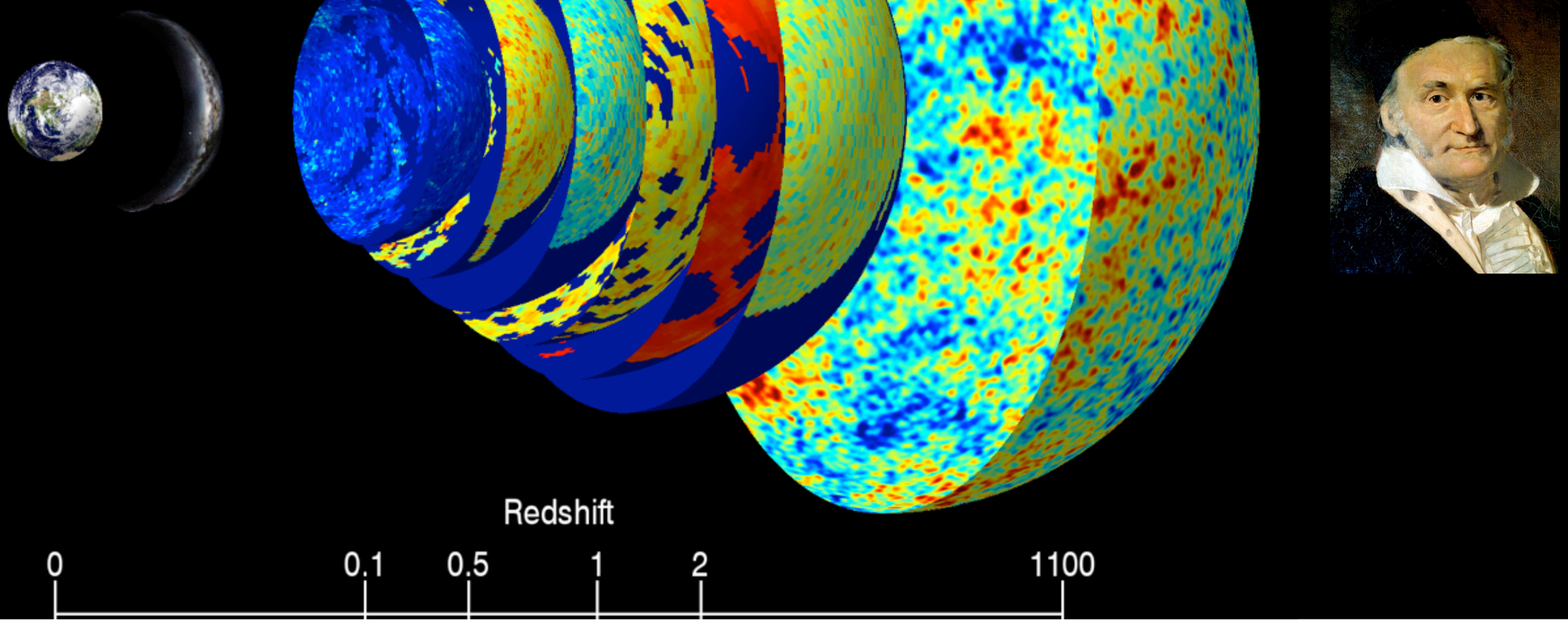


Constraining non-Gaussianity with LSS and ISW data: results and open issues

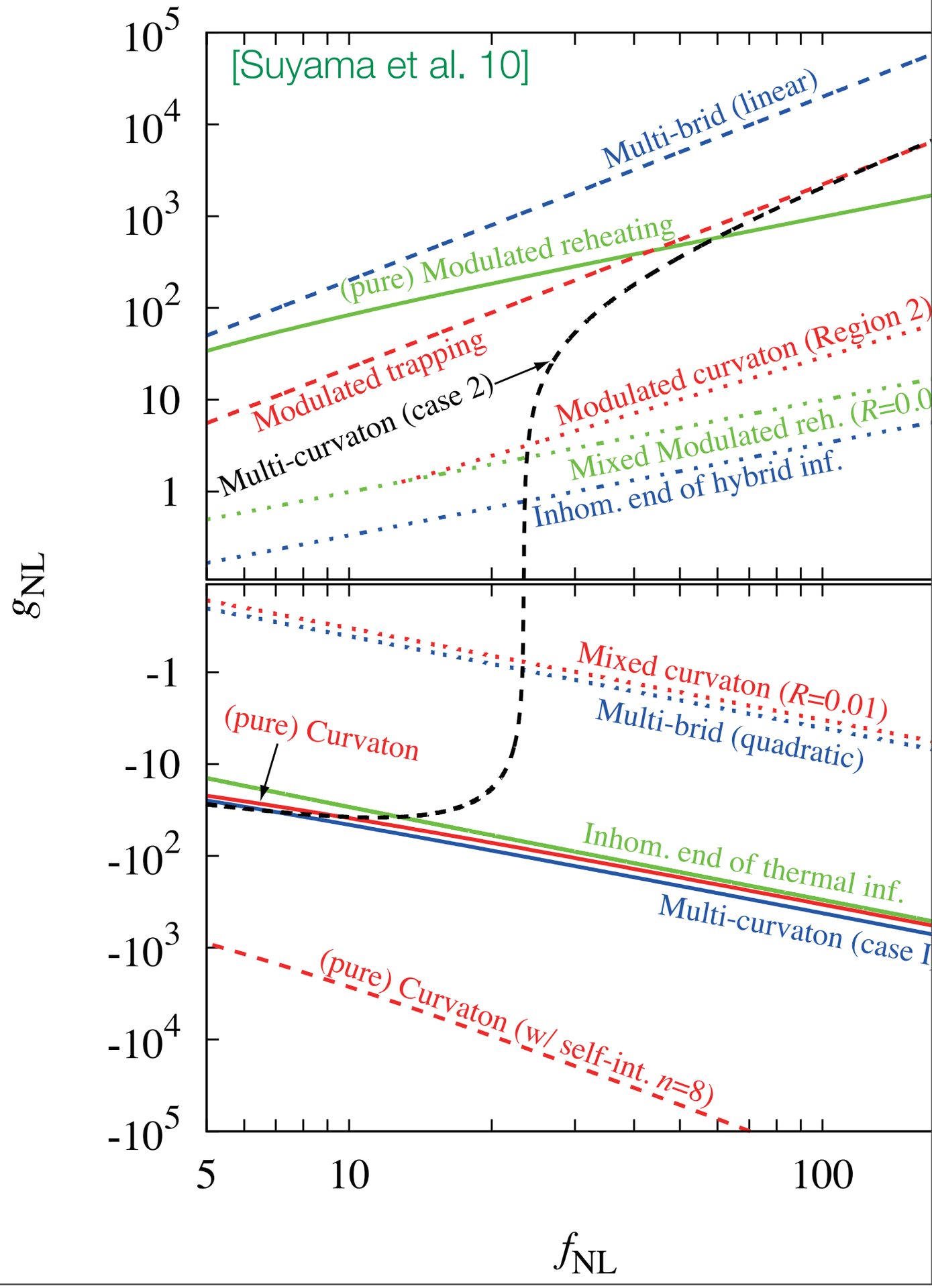
Tommaso Giannantonio
LMU Munich & Excellence Cluster

Outline

- Large-scale structure and non-Gaussianity: non-local, scale-dependent bias
- Updated LSS + integrated Sachs-Wolfe (ISW) data: Luminous Red Galaxies from BOSS & systematics
- Combined measurement of f_{NL} from LSS+ISW data & systematics
- Extension to galaxy clusters
- Forecasts with DES and Euclid
- Conclusions

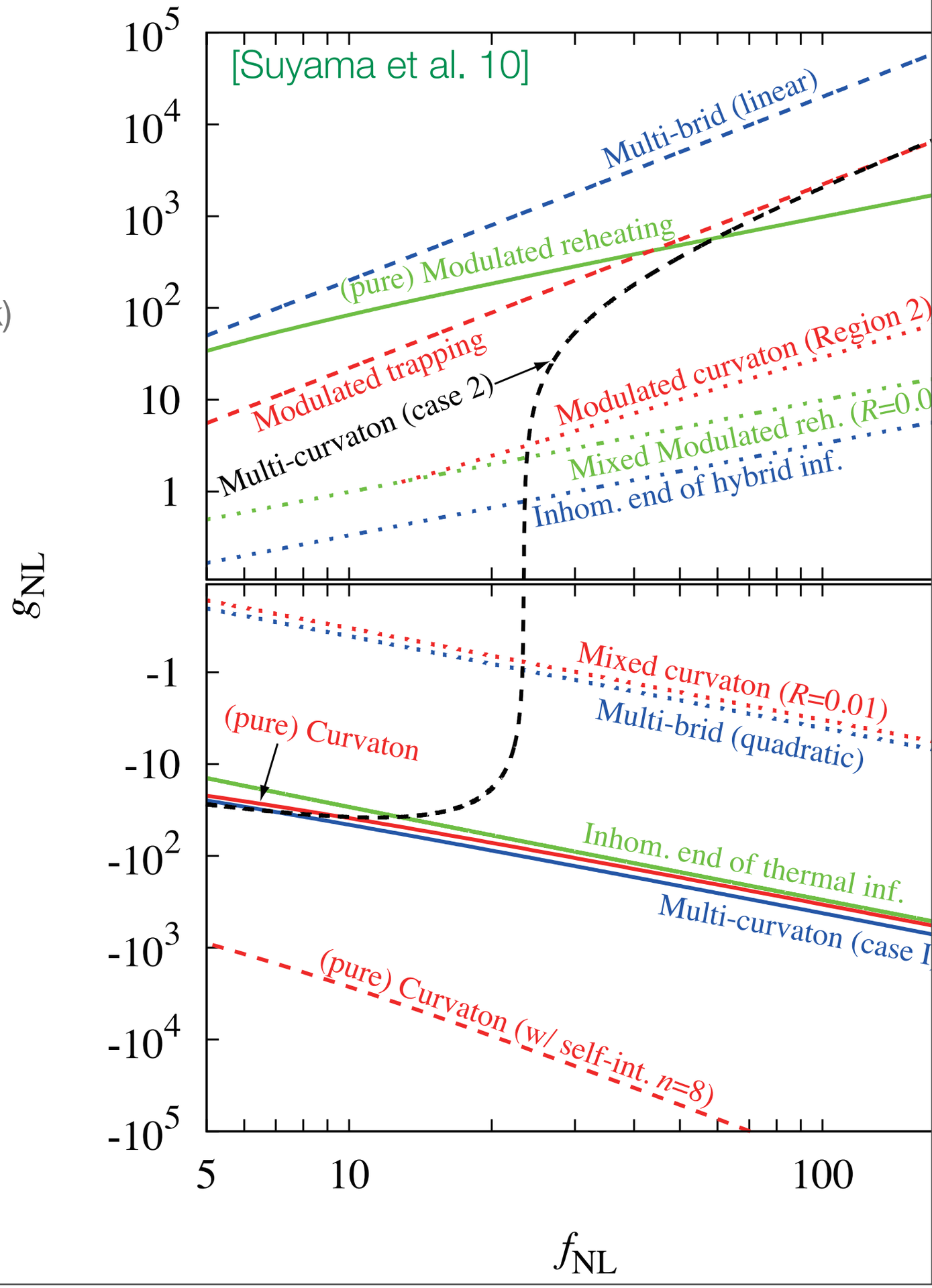
Collaborators: A. Ross, R. Crittenden, W. Percival, B. Nichol, C. Porciani, J. Weller, M. Kilbinger, A. Mana, G. Hütsi

Constraining (?) the early universe



Constraining (?) the early universe

- **Many** models available (-> S. Yamaguchi's talk)
  - single field
  - many fields
  - slow or fast decay
  - various possible kinetic terms
  - cyclic/ekpyrotic models...



Constraining (?) the early universe

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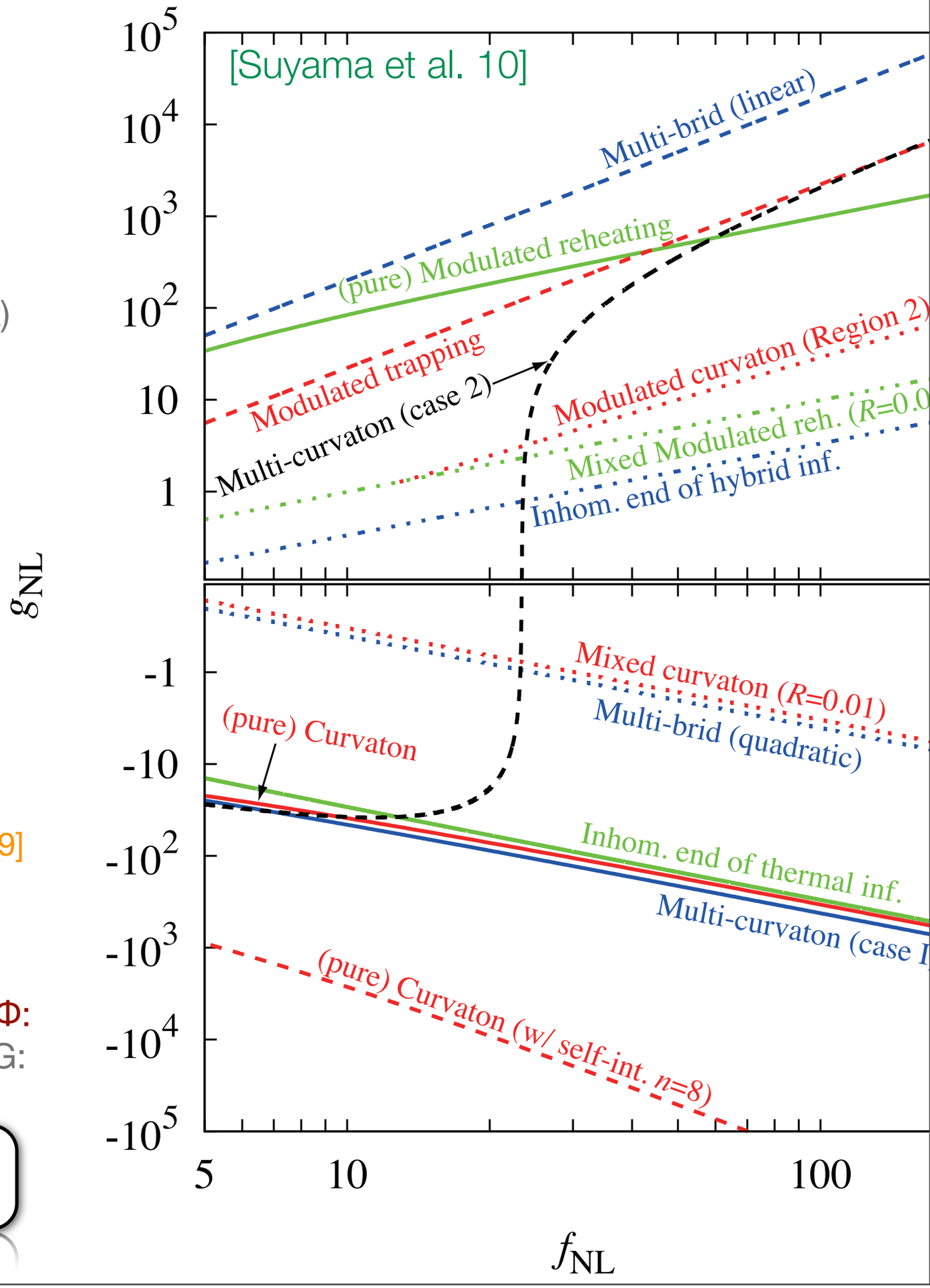
  - single field
  - many fields
  - slow or fast decay
  - various possible kinetic terms
  - cyclic/ekpyrotic models...

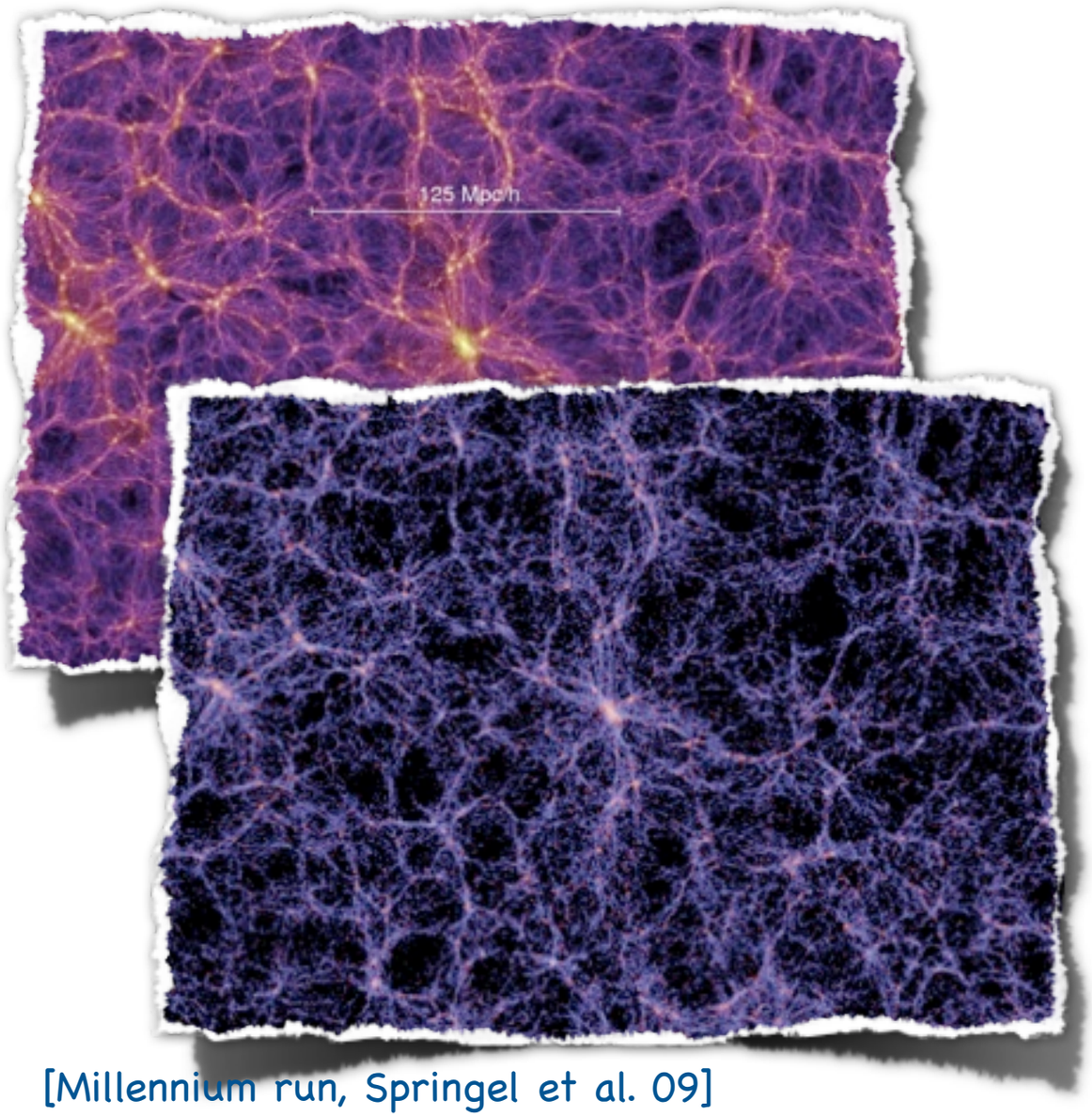
- Simplest single-field models predict:
  1. near-flatness ✓
  2. nearly scale-invariant power spectrum ✓
  3. curvature perturbations only ~ [Valiviita & TG 09] - see talk by D. Langlois
  4. nearly Gaussian distribution ?

- Other models: many configurations: kernel W. Φ: primordial potential; ϕ Gaussian. Amount of NG: skewness **f_{NL}**

$$\Phi(\mathbf{x}, z_*) = \varphi(\mathbf{x}, z_*) + (f_{\rm NL} * W * \varphi * \varphi)(\mathbf{x}, z_*)$$



Non-Gaussianity and the LSS



[Millennium run, Springel et al. 09]

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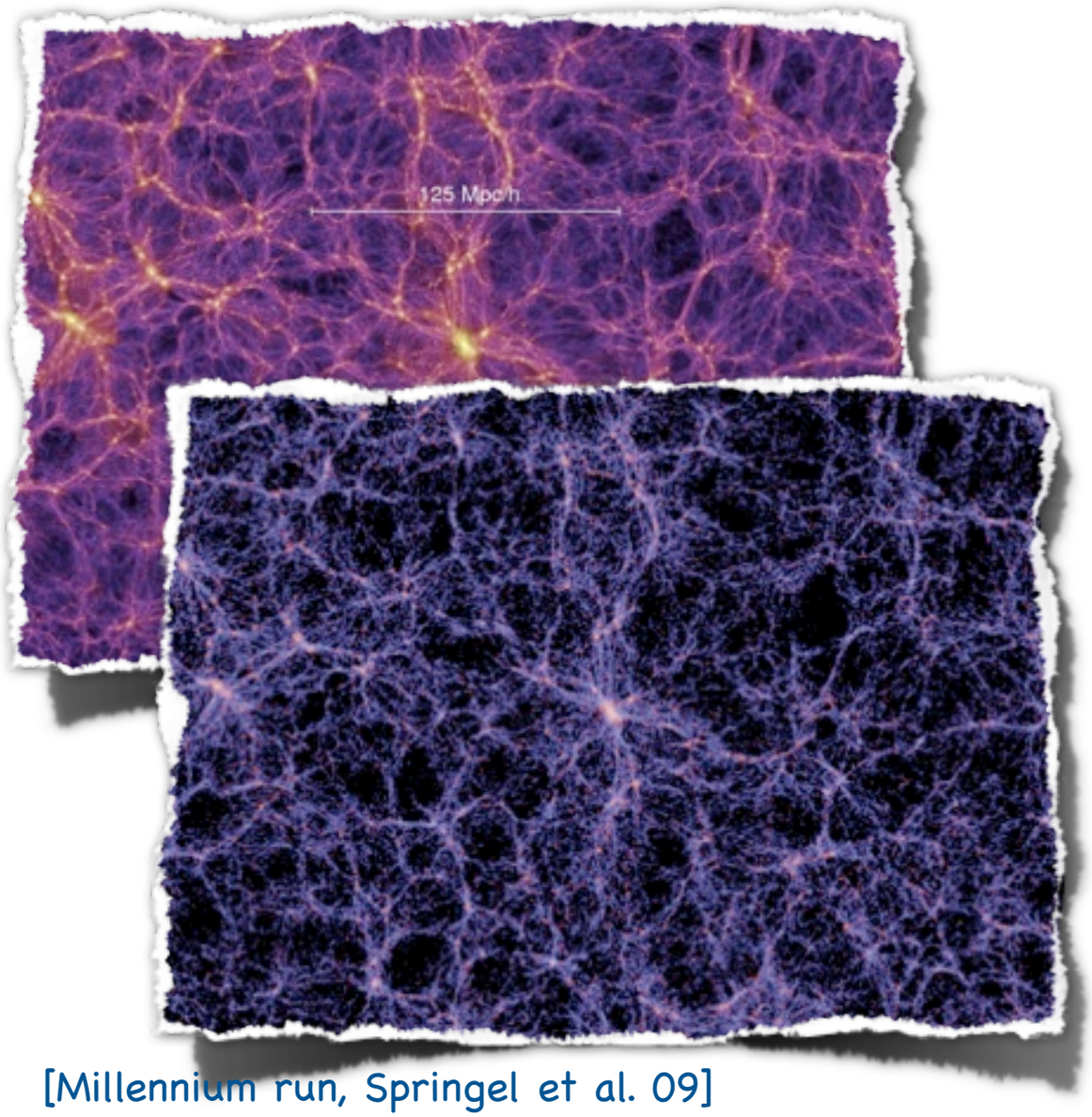

[Millennium run, Springel et al. 09]

- Dark matter perturbations δ_m > d.m. haloes δ_h > galaxies δ_g
  - halo mass function:
    halo bias, $\delta_h = b_h \delta_m$
  - halo occupation distribution:
    galaxy bias, $\delta_g = b_g \delta_m$

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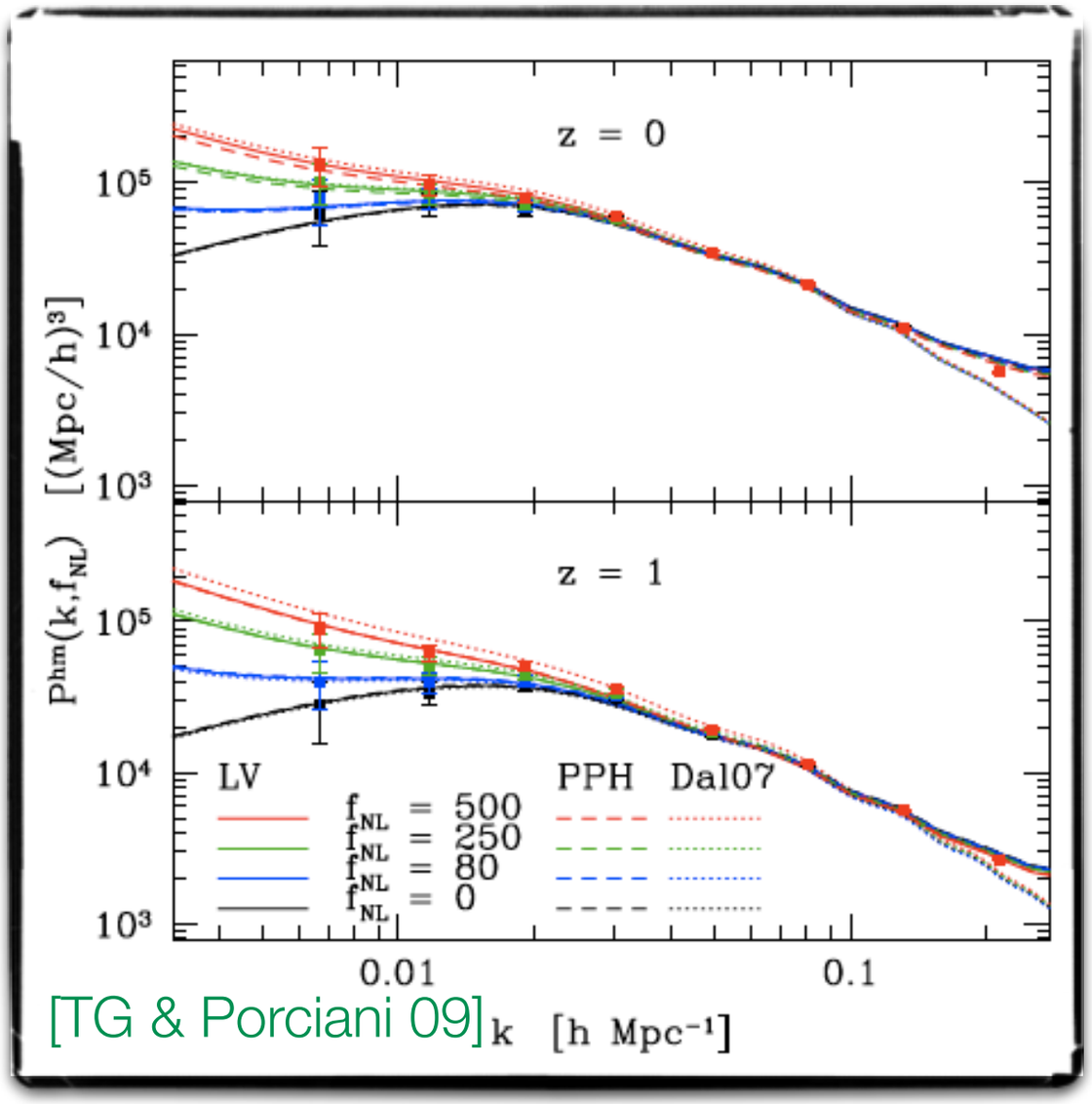


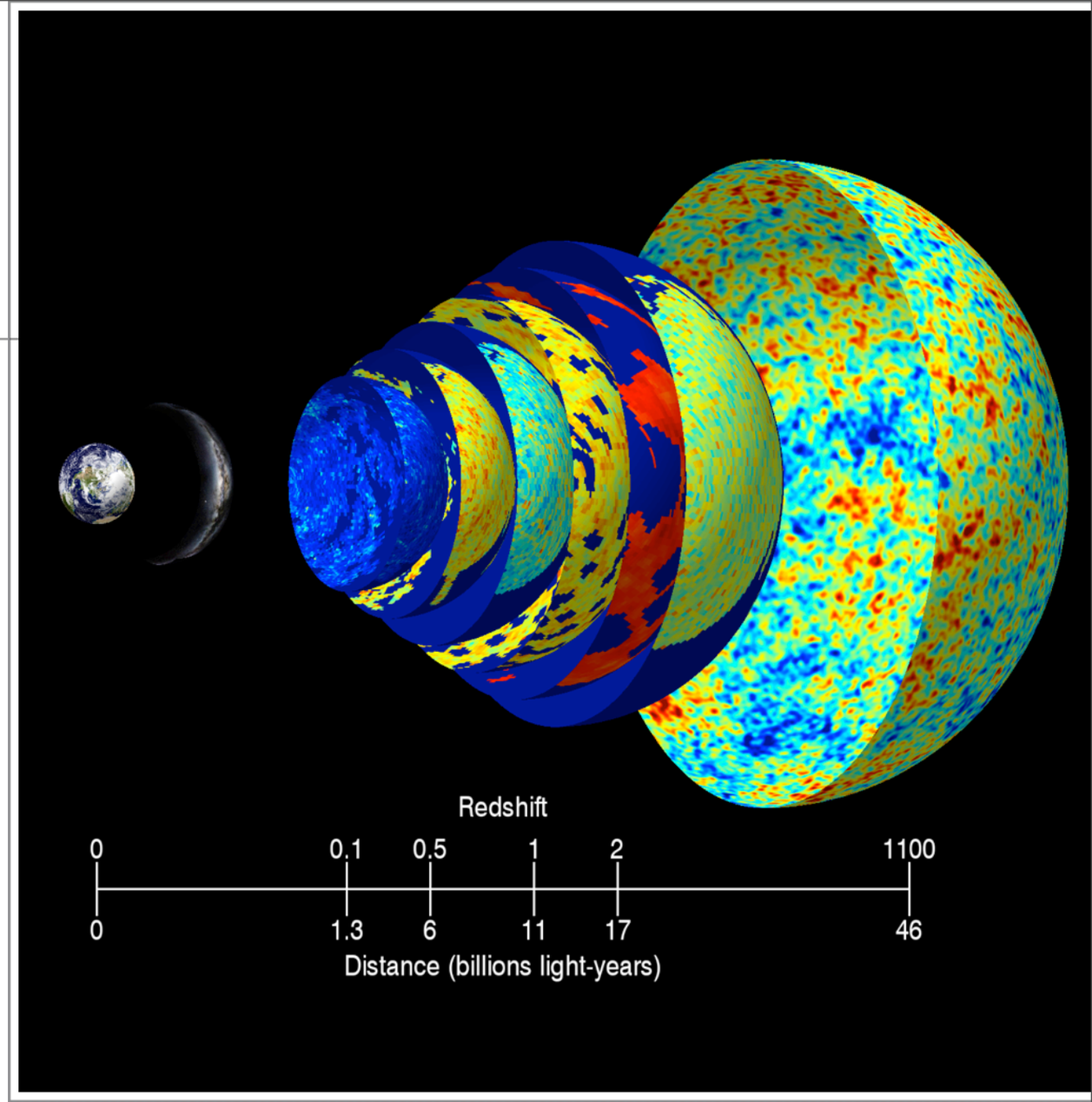
[TG & Porciani 09]

$$b(k, f_{NL}) = b_{Gaus} + \delta b(f_{NL}) + \Delta b(k, f_{NL})$$

$$\Delta b(k, f_{NL}) \propto \mathbf{f_{NL}}(b_{Gaus} + \delta b - 1)\, \mathbf{k^{-2}}$$

- Dark matter perturbations δ_m > d.m. haloes δ_h > galaxies δ_g
  - halo mass function: halo bias, $\delta_h = b_h\, \delta_m$
  - halo occupation distribution: galaxy bias, $\delta_g = b_g\, \delta_m$
- PNG: scale-dependent, **non-local** b [Dalal et al 07, +]
- Spectra ‹gal-gal› ~ b^2 and ‹gal-CMB› ~ b: constraints on PNG! [Slosar et al 08, Xia et al 10, 11, Ross et al. 12]
- Also small effect on P_{matter} from bispectrum [Taruya et al 08]

Combined LSS + ISW analysis, updated [TG et al. 08,12]



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- **Data maps**, pixellated
  - density: 6 galaxy catalogues: **2MASS**, **SDSS** (main gal **DR8**, **LRG**, **QSO**), **NVSS**, **HEAO**
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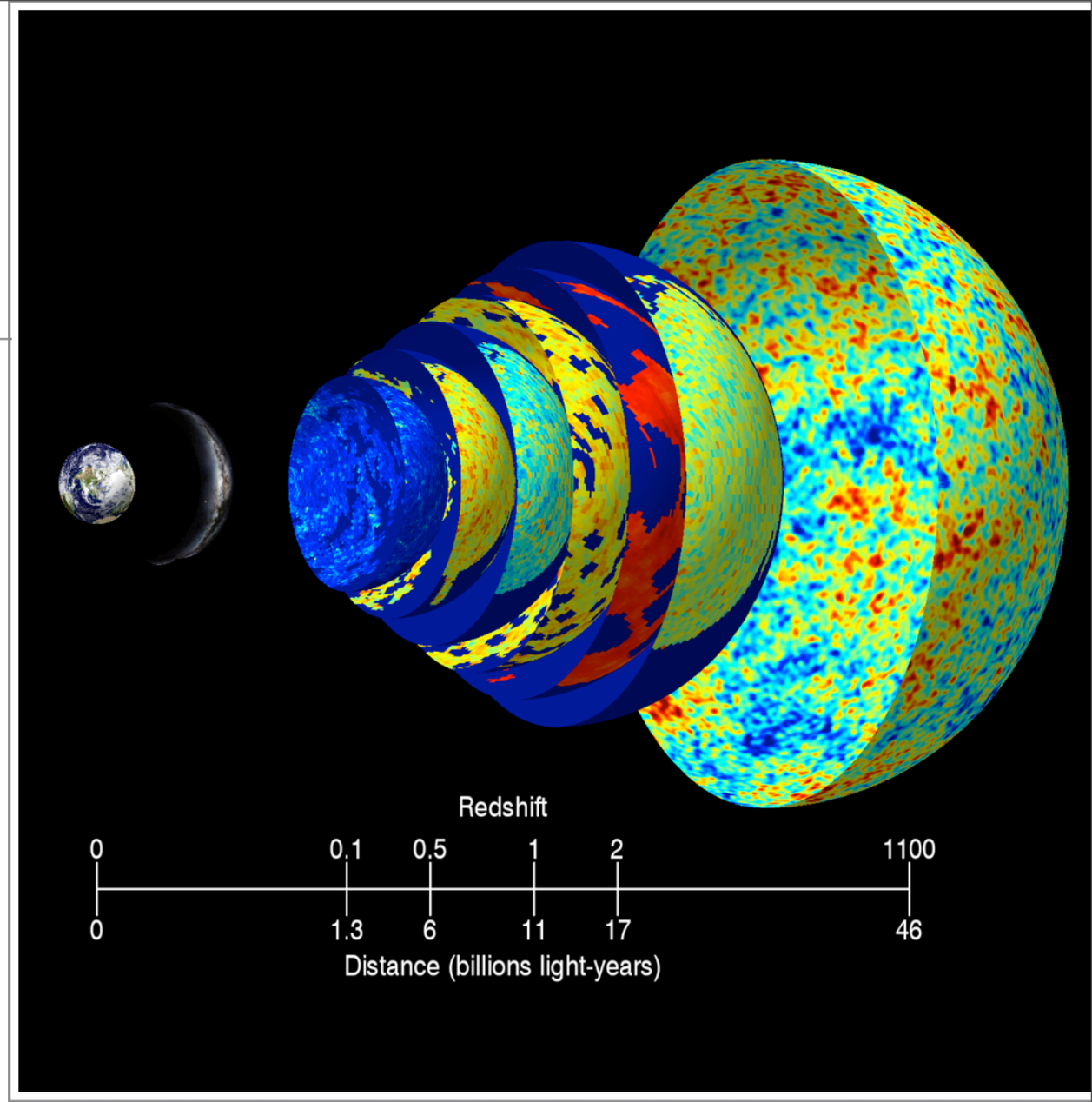

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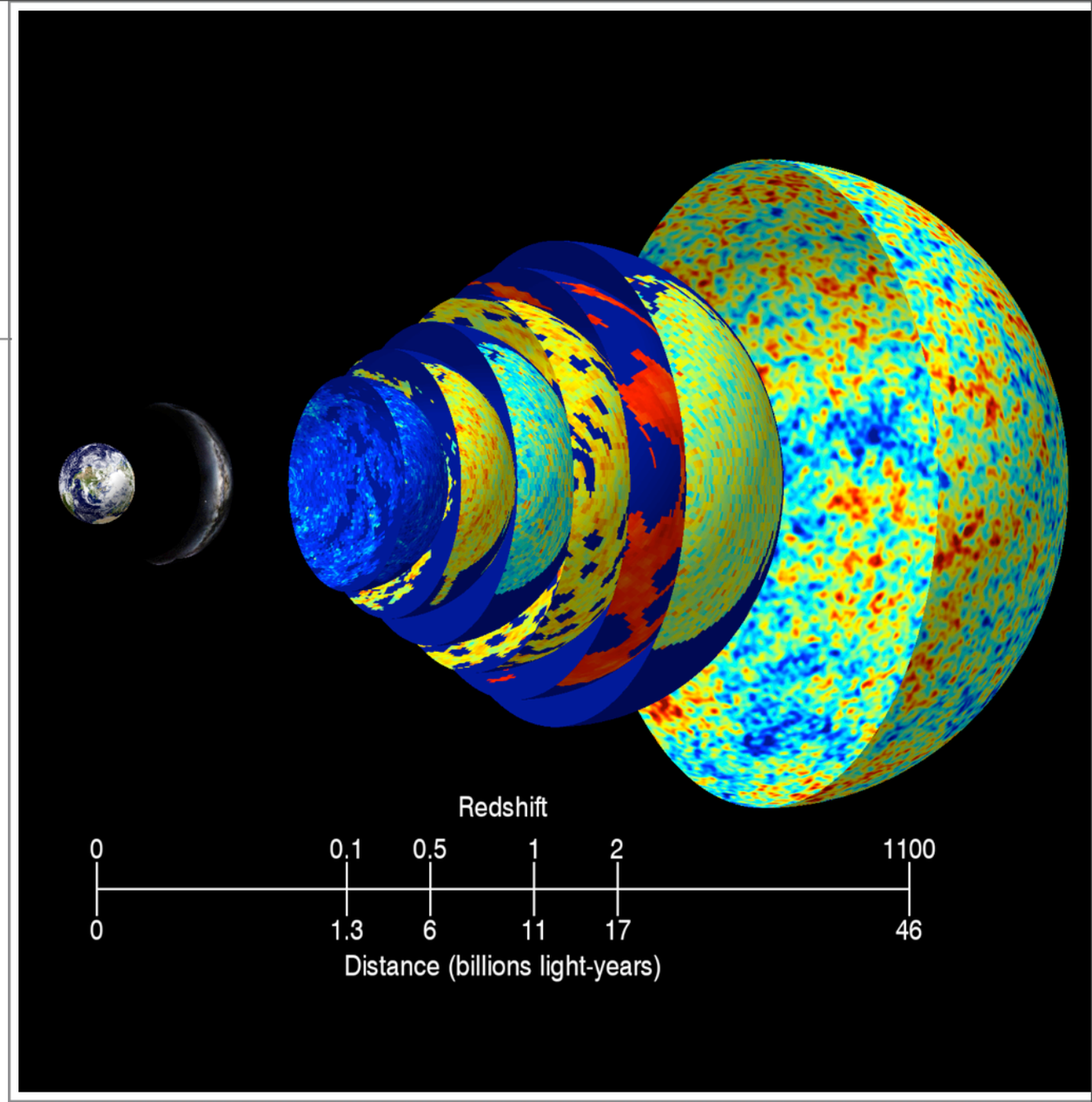

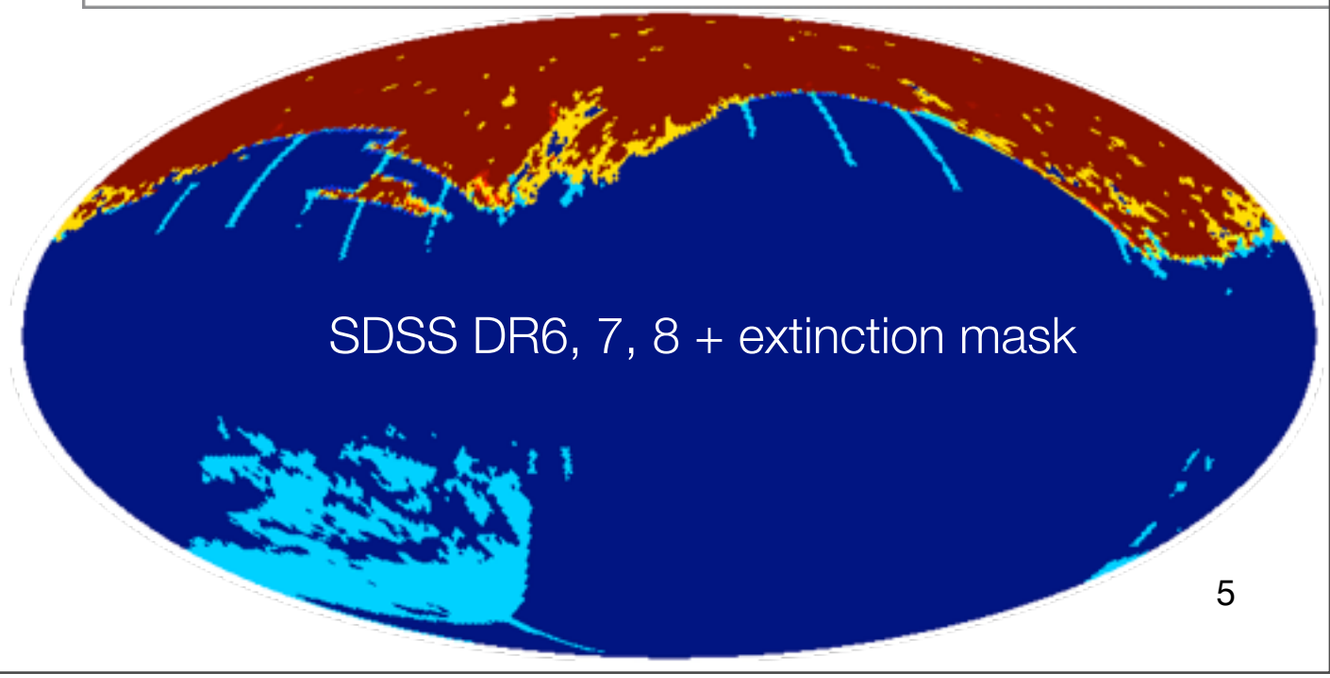

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- **Masks**
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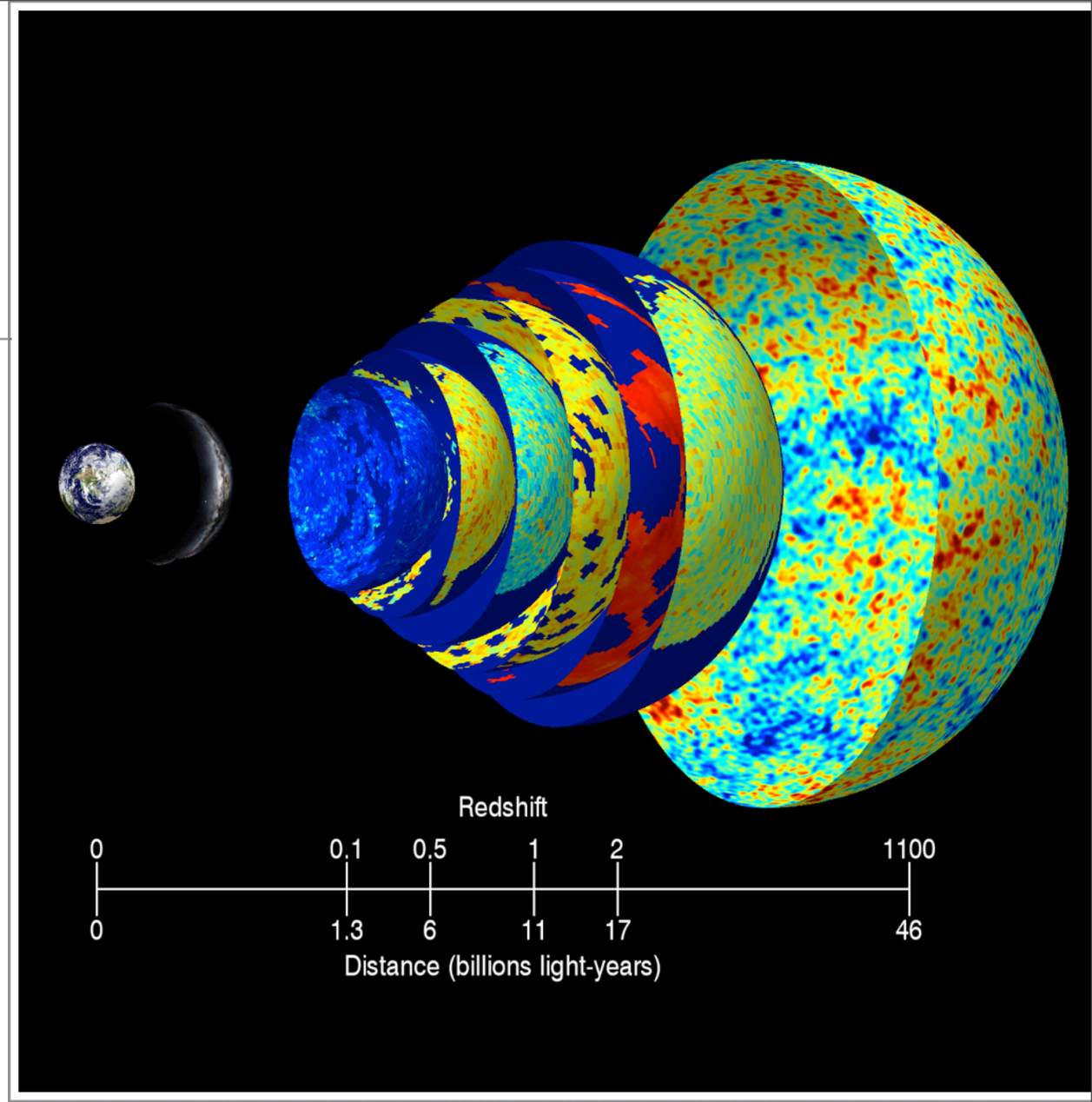
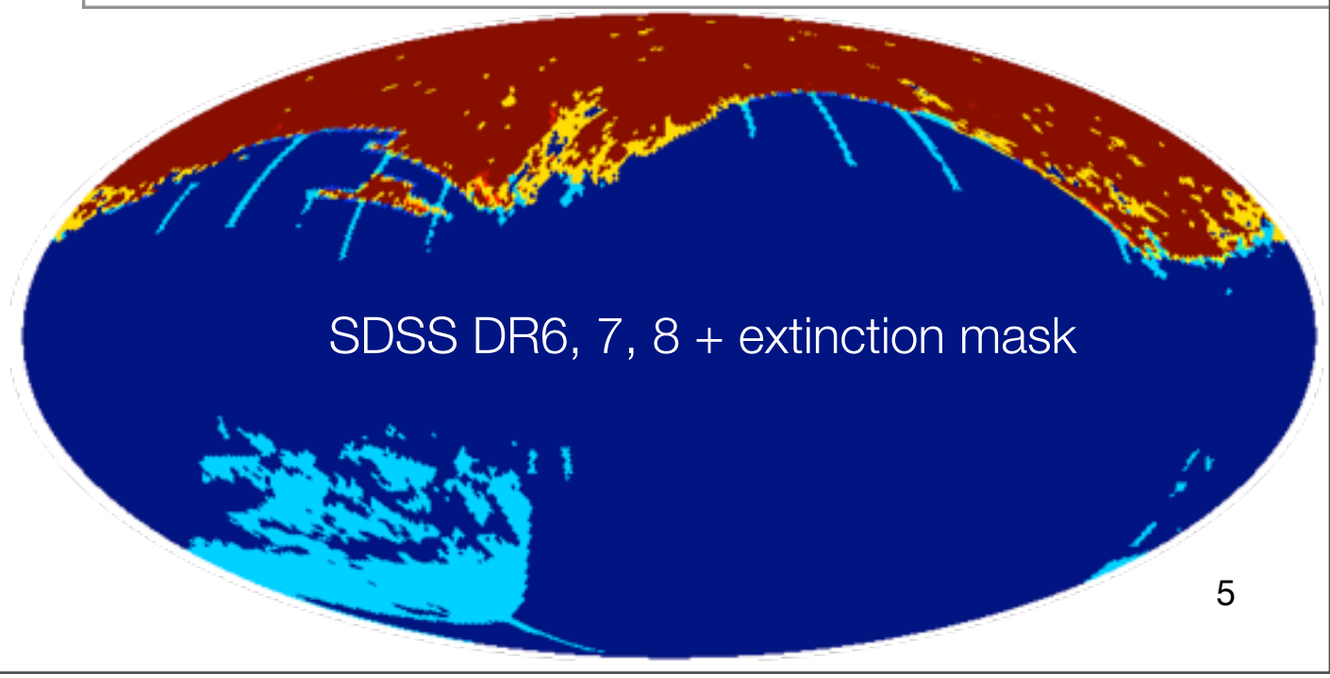
- **Observables**: 2D two-point correlations

$$w^{ISWg}(\vartheta) \equiv \langle \Theta^{ISW}(\hat{\mathbf{n}}_1)\delta^g(\hat{\mathbf{n}}_2)\rangle \propto b$$

$$w^{gg}(\vartheta) \equiv \langle \delta^g(\hat{\mathbf{n}}_1)\delta^g(\hat{\mathbf{n}}_2)\rangle \propto b^2$$

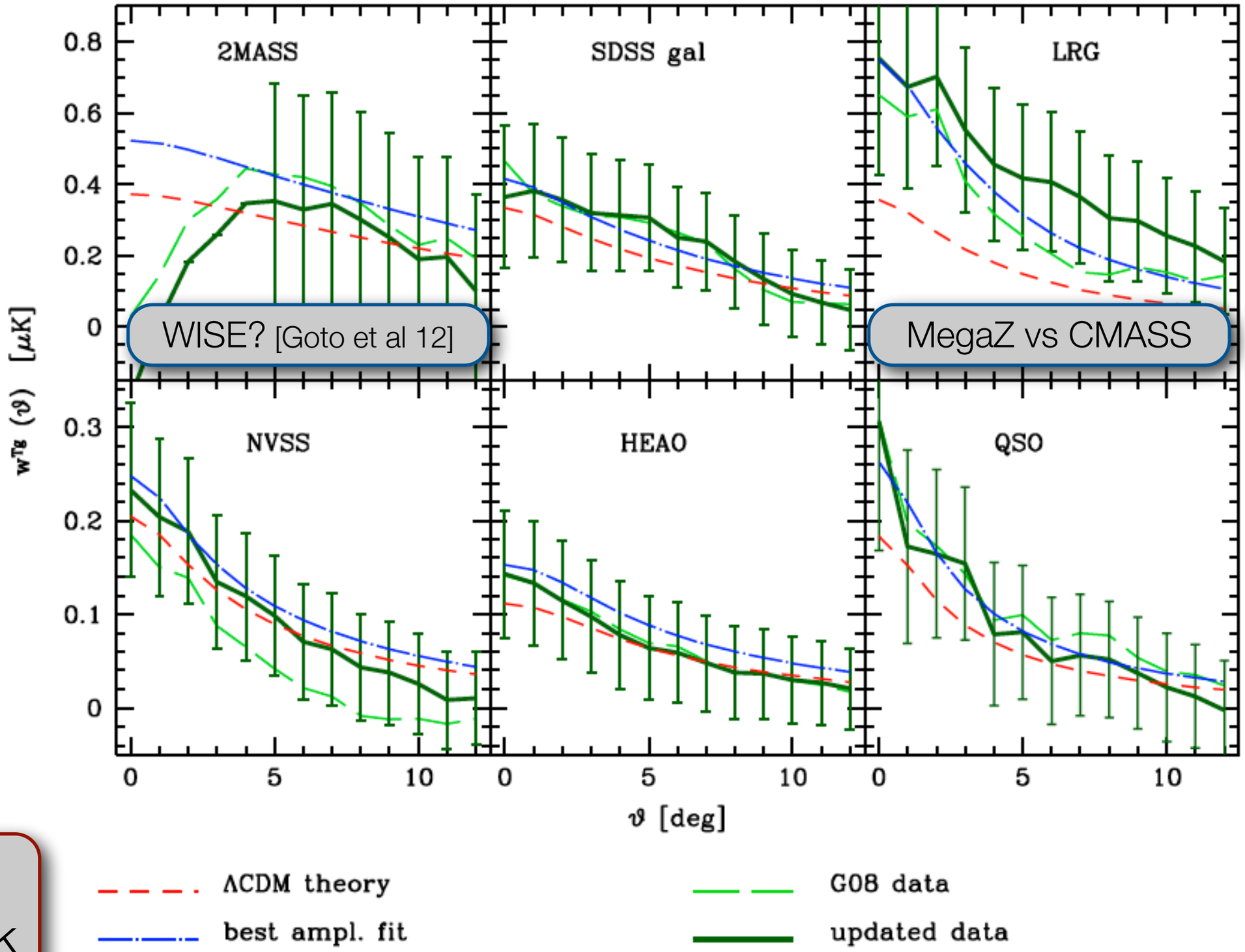




Measured ⟨Tg⟩ correlations

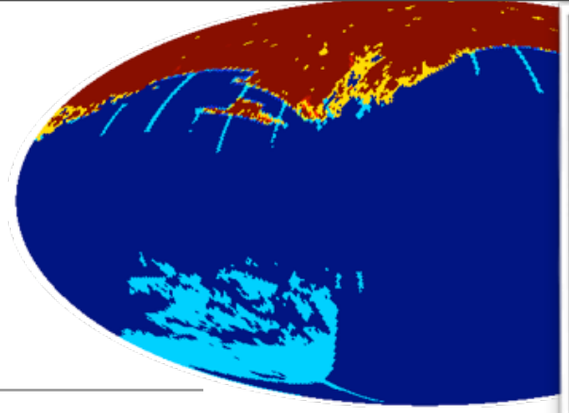
[TG et al. 12, MNRAS]

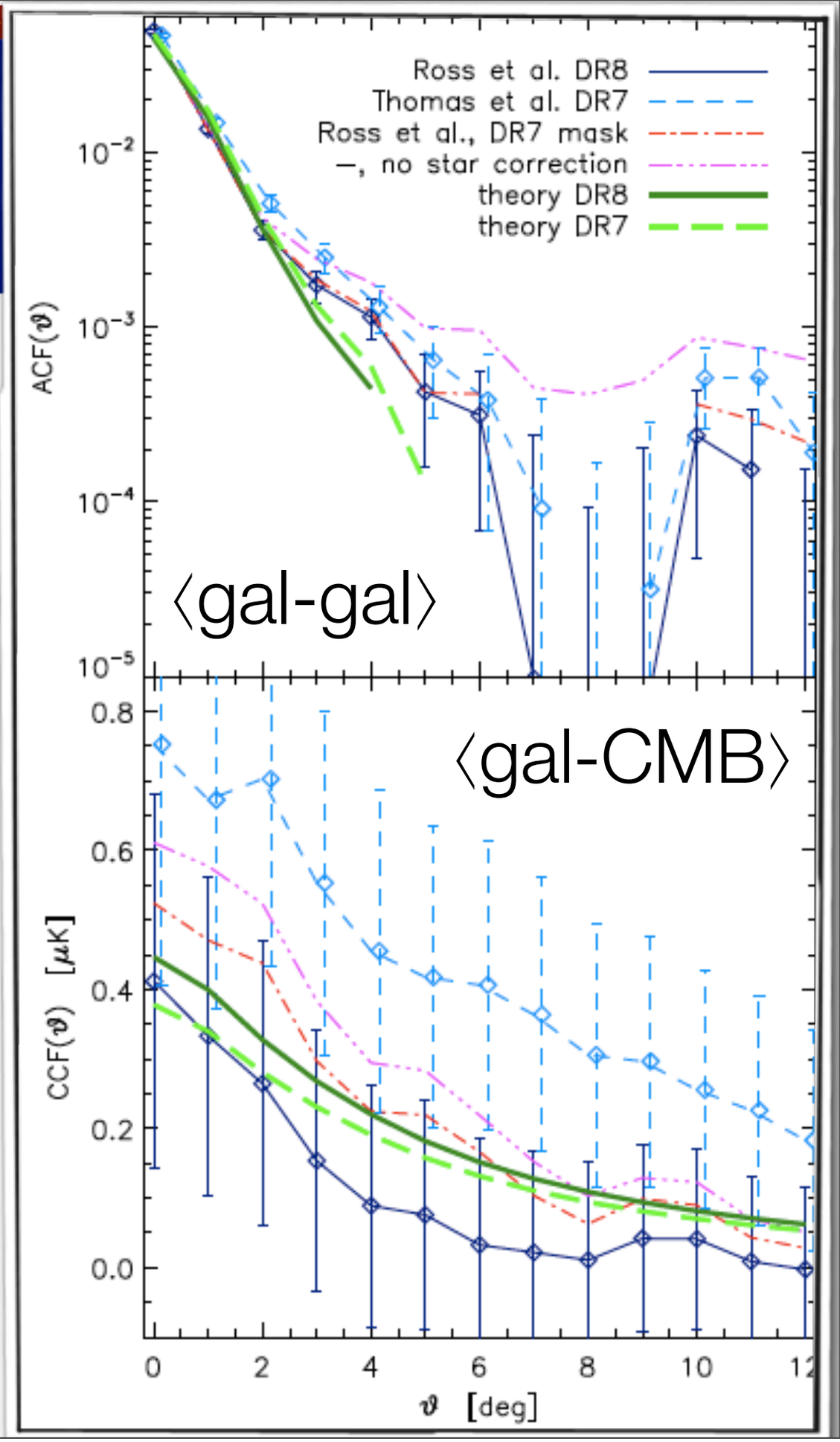
- Non-zero only with dark energy
- Covariance: Monte Carlos
- ~ agrees with LCDM & older data
- **Total S/N = 4.4 σ (± 0.4)** (single amplitude fitting)



Independent evidence for Dark Energy at >4σ

LRG comparison





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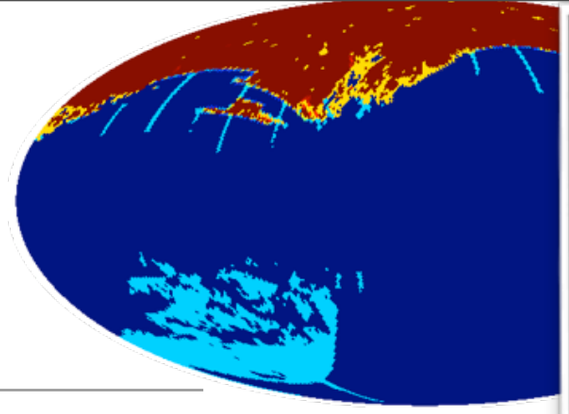

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- Similar redshift range, Ross et al. South coverage (DR8)
- Ross et al.: correction for stellar systematics
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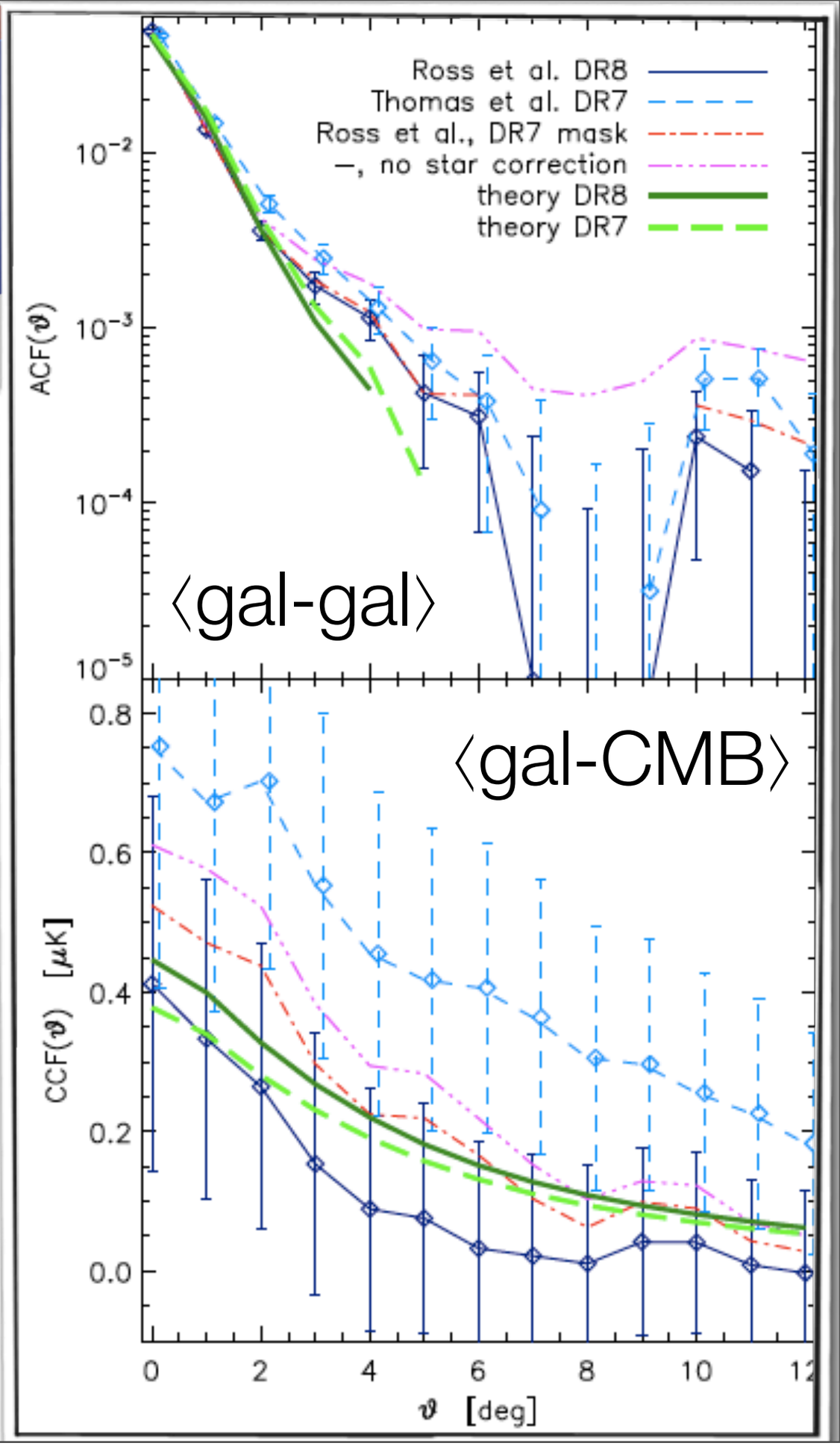
  - Large proportion (15%) with BOSS spectra



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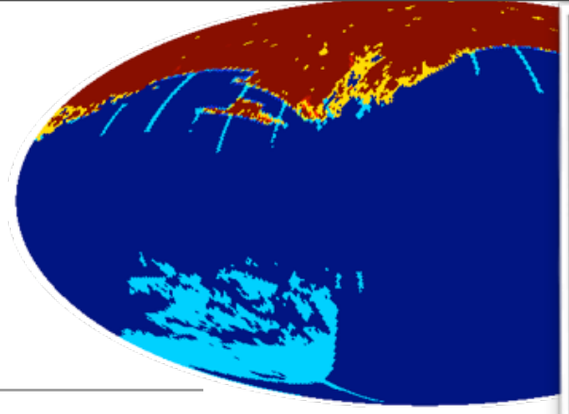

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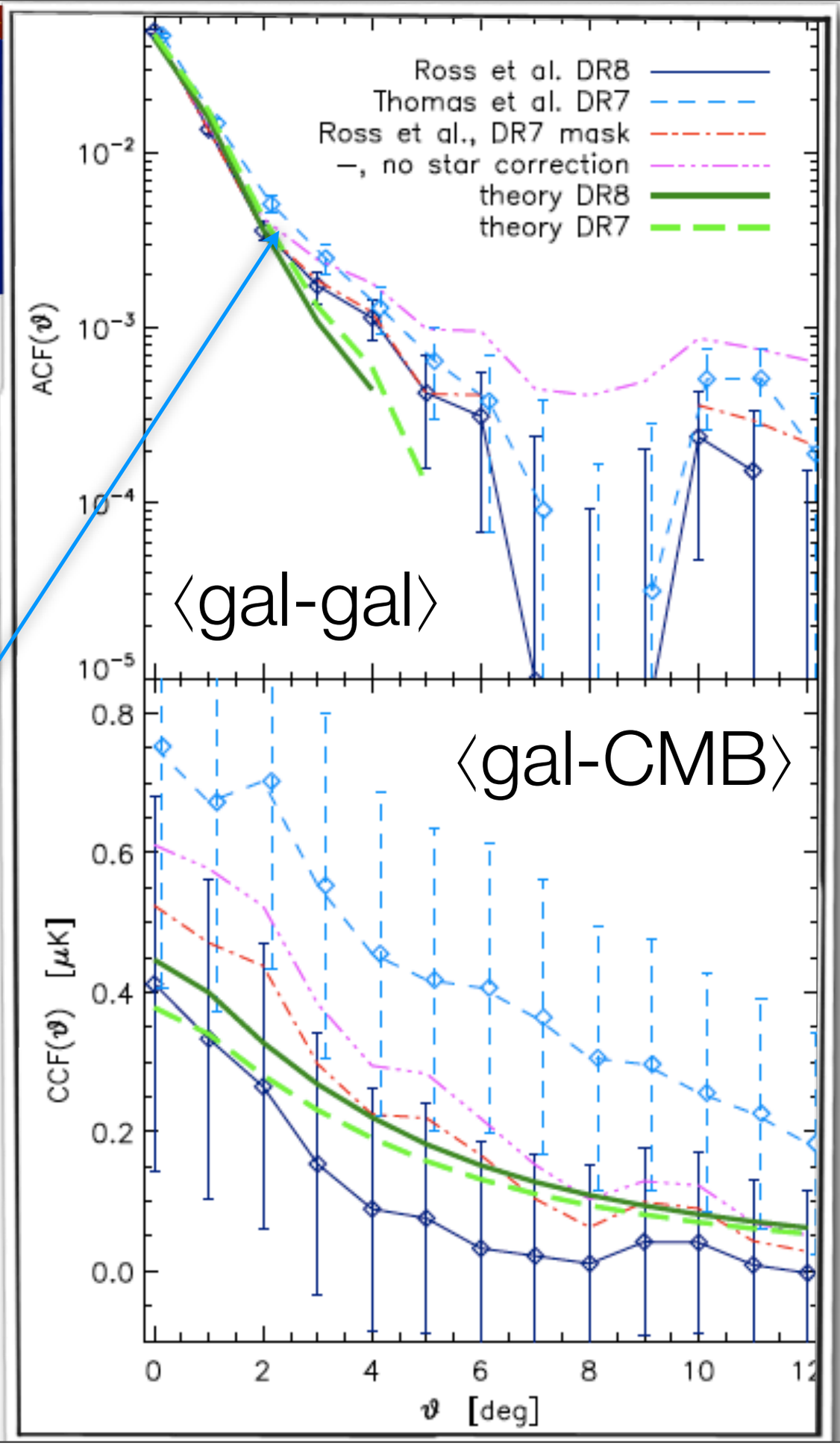

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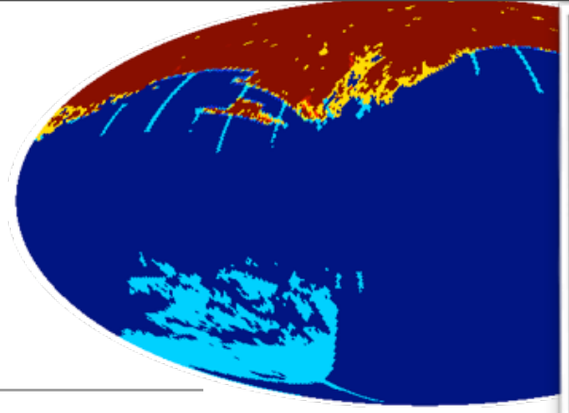

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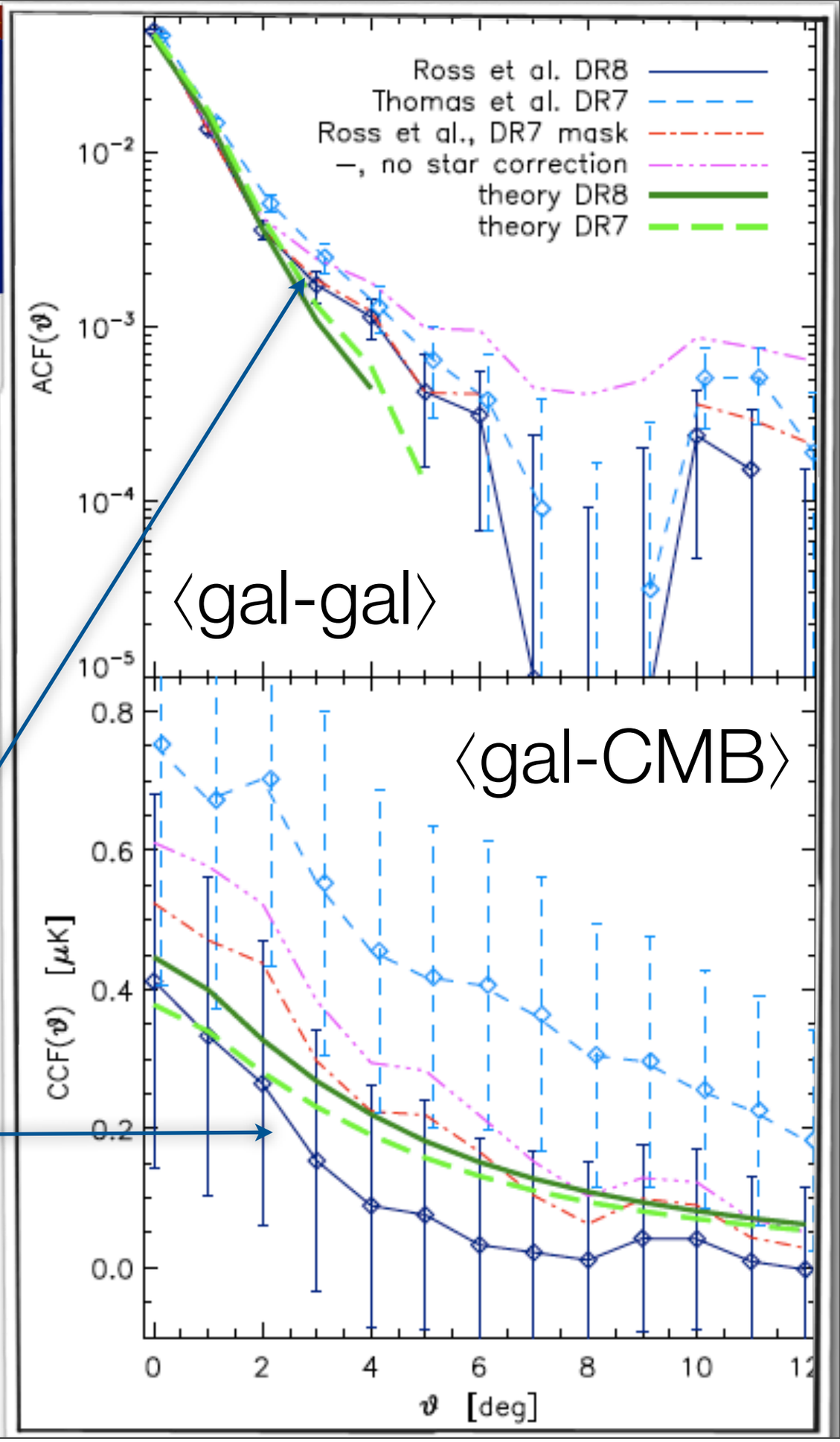

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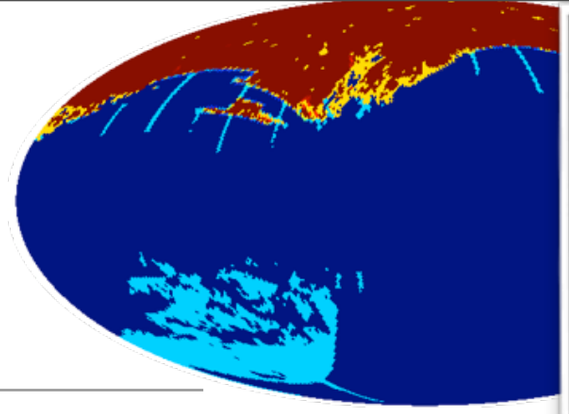

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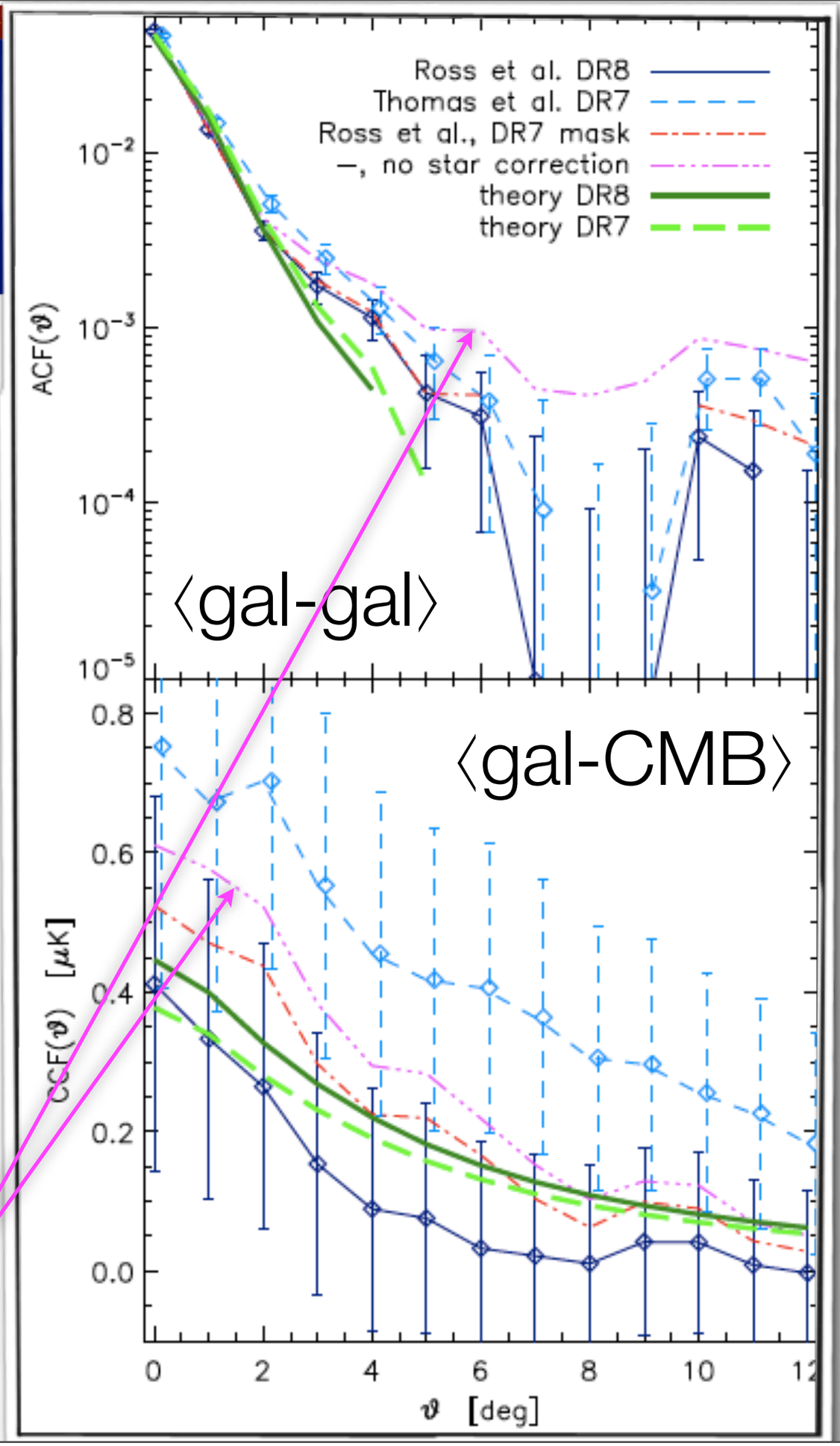

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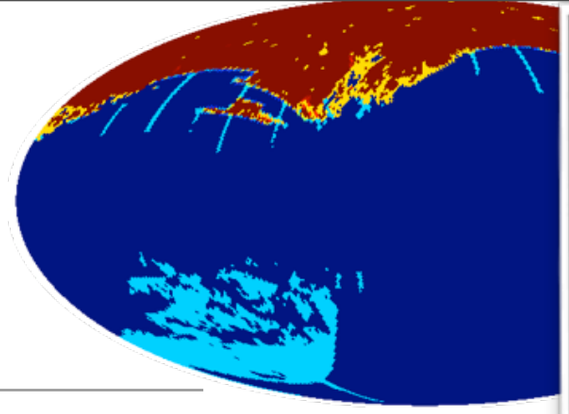

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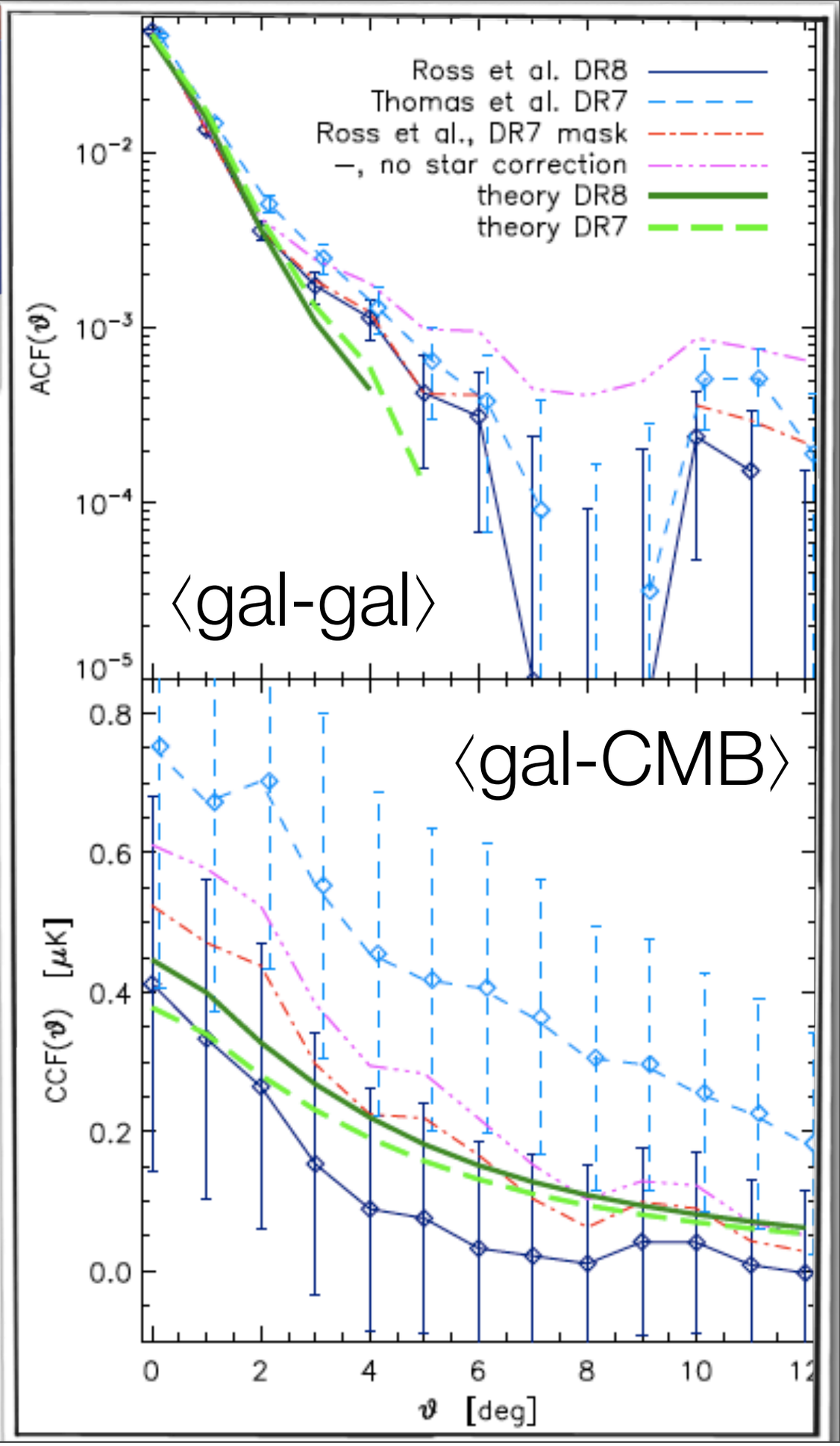
ACF at large scales: tricky



LRG systematics

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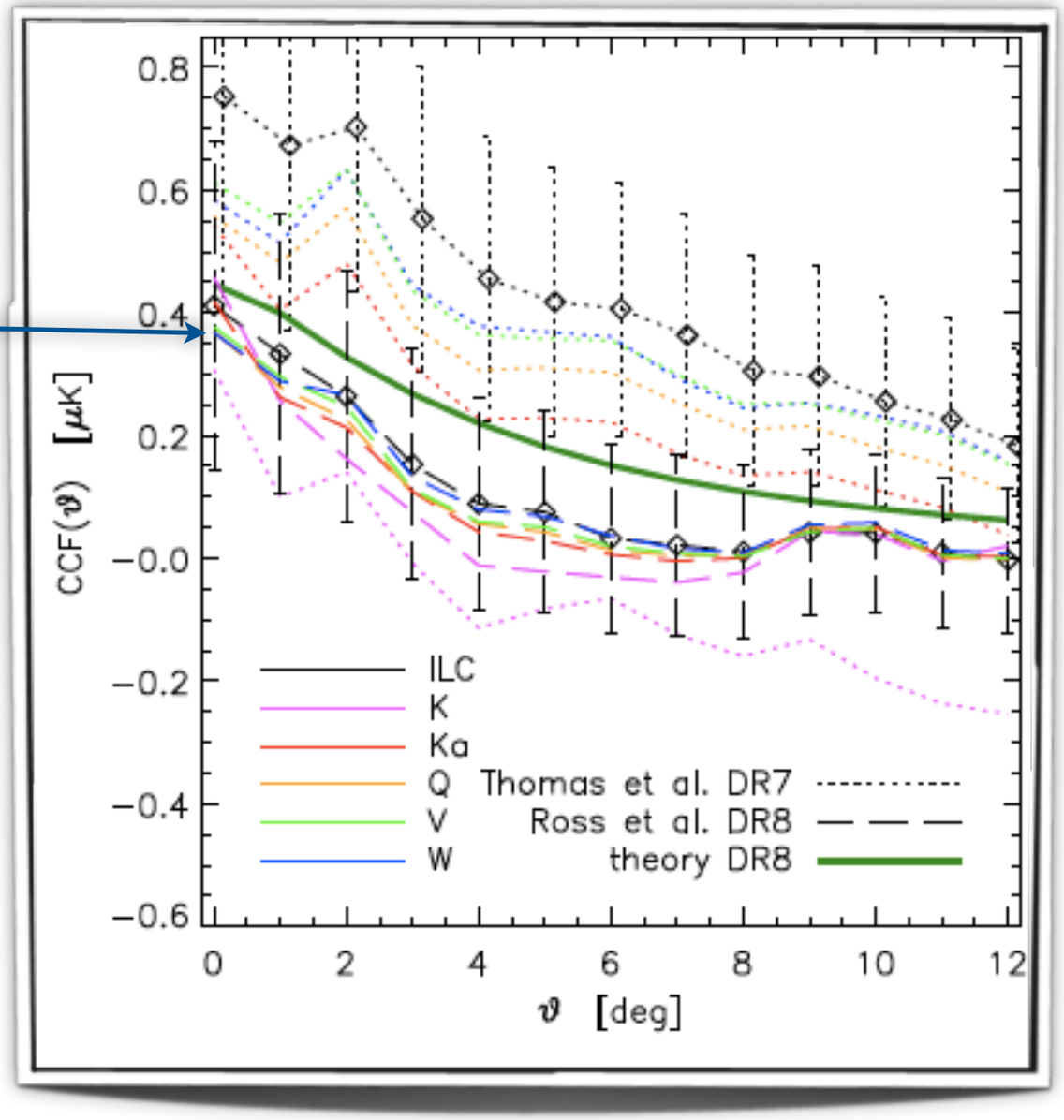
- Frequency independence:
  - Very stable CCF, with all WMAP bands!
  - Evidence for superior quality of Ross et al. data
  - Stellar contamination negligible

- **Total ISW S/N down to 4.0; better agreement with LCDM**



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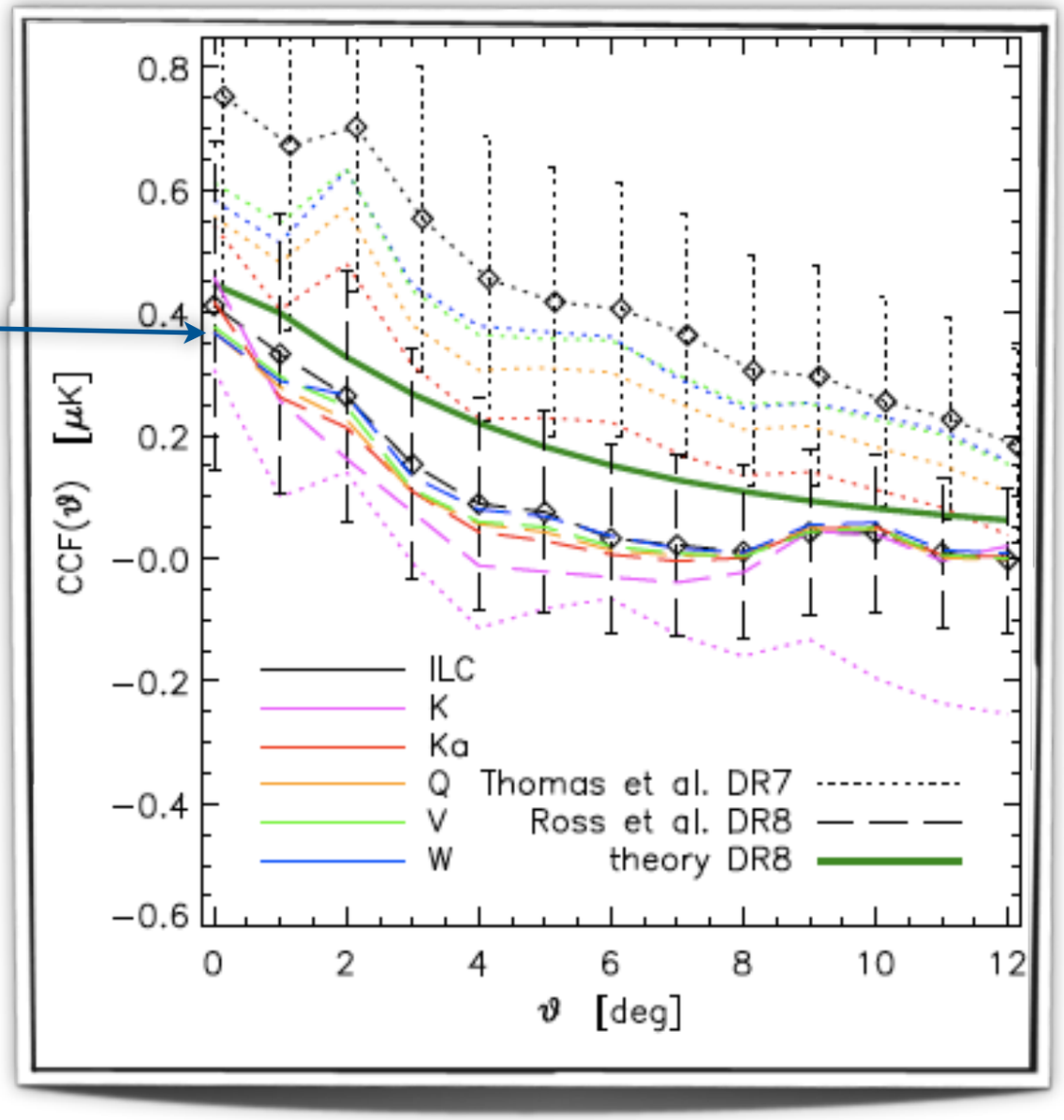
Use these!

Now suitable for f_{NL} analysis.



Full bias analysis of LSS + ISW data & f_{NL}

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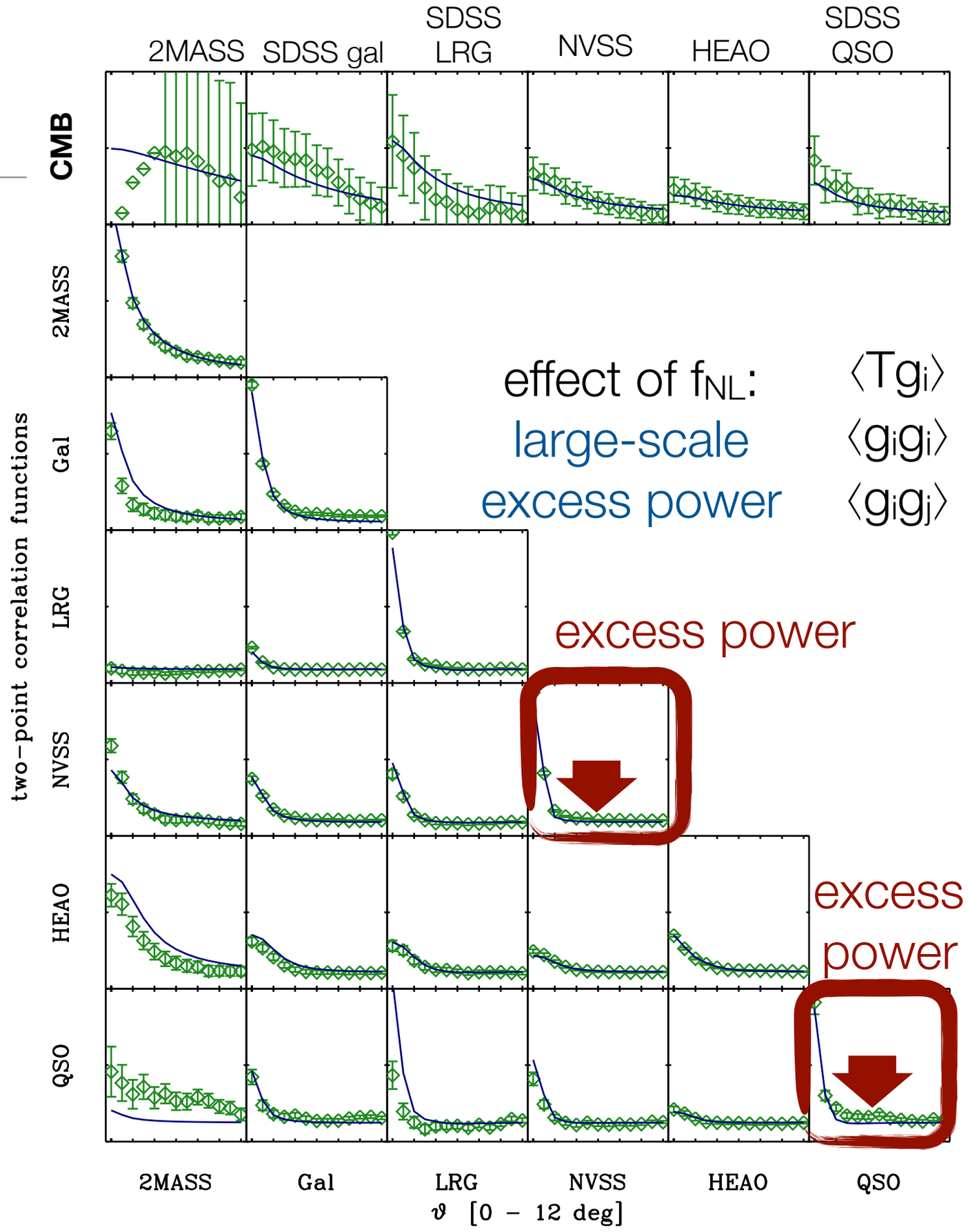
- Measure (local) **f_{NL}** via b
- Not only **⟨Tg⟩** ∝ b, but also ALL **⟨gg⟩** ∝ b^2 correlations
- **Data**: all 27 2-pt functions!



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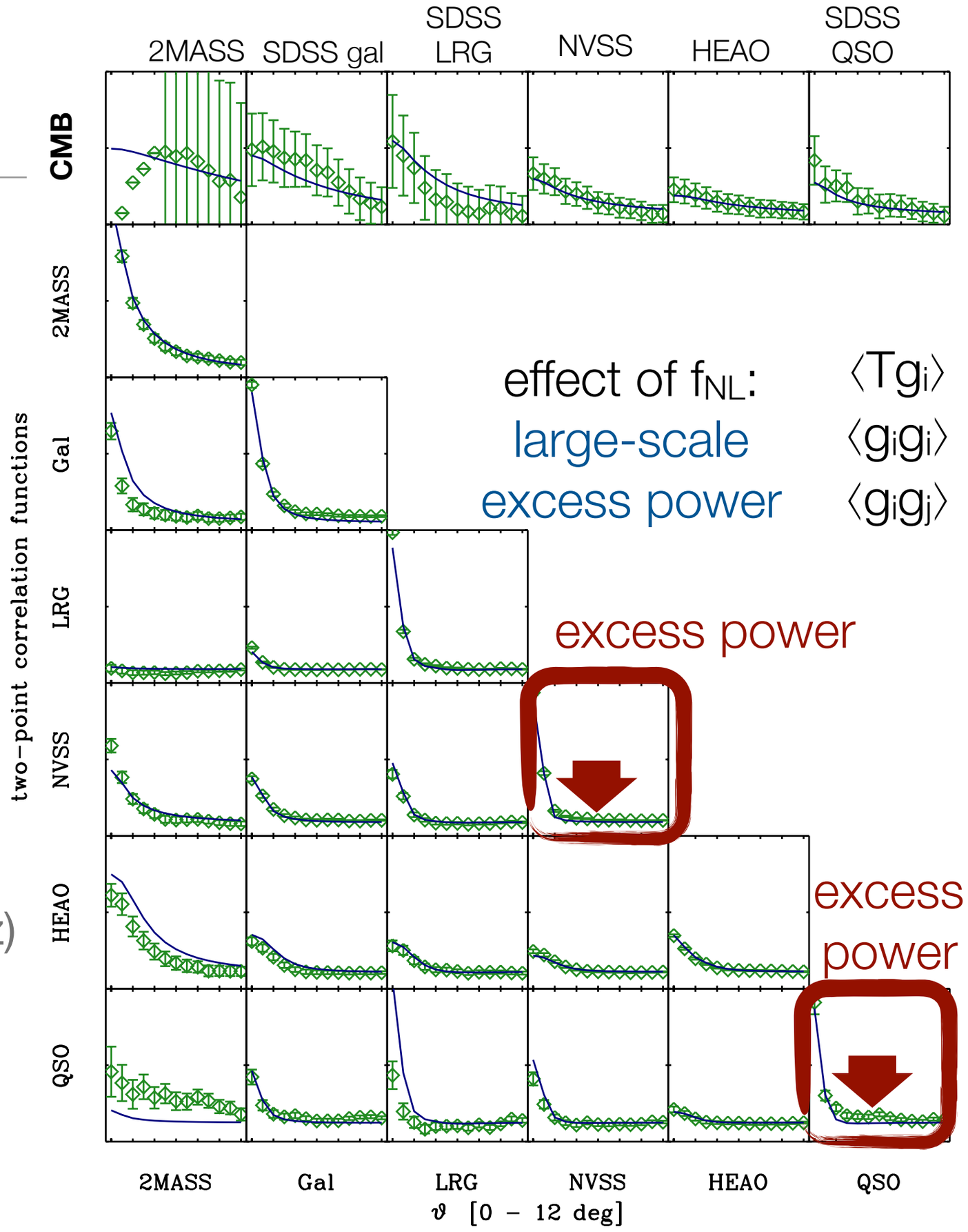
- **Data**: all 27 2-pt functions!

- For each catalogue we model $b_i(k,z) = b_i(z) + \Delta b\,(k,z)$
- Several models for Gaussian b:
  - constant $b_i(z) = b_{0i}$
  - evolving $b_i(z) = 1 + (b_{0i} - 1) / D(z)$

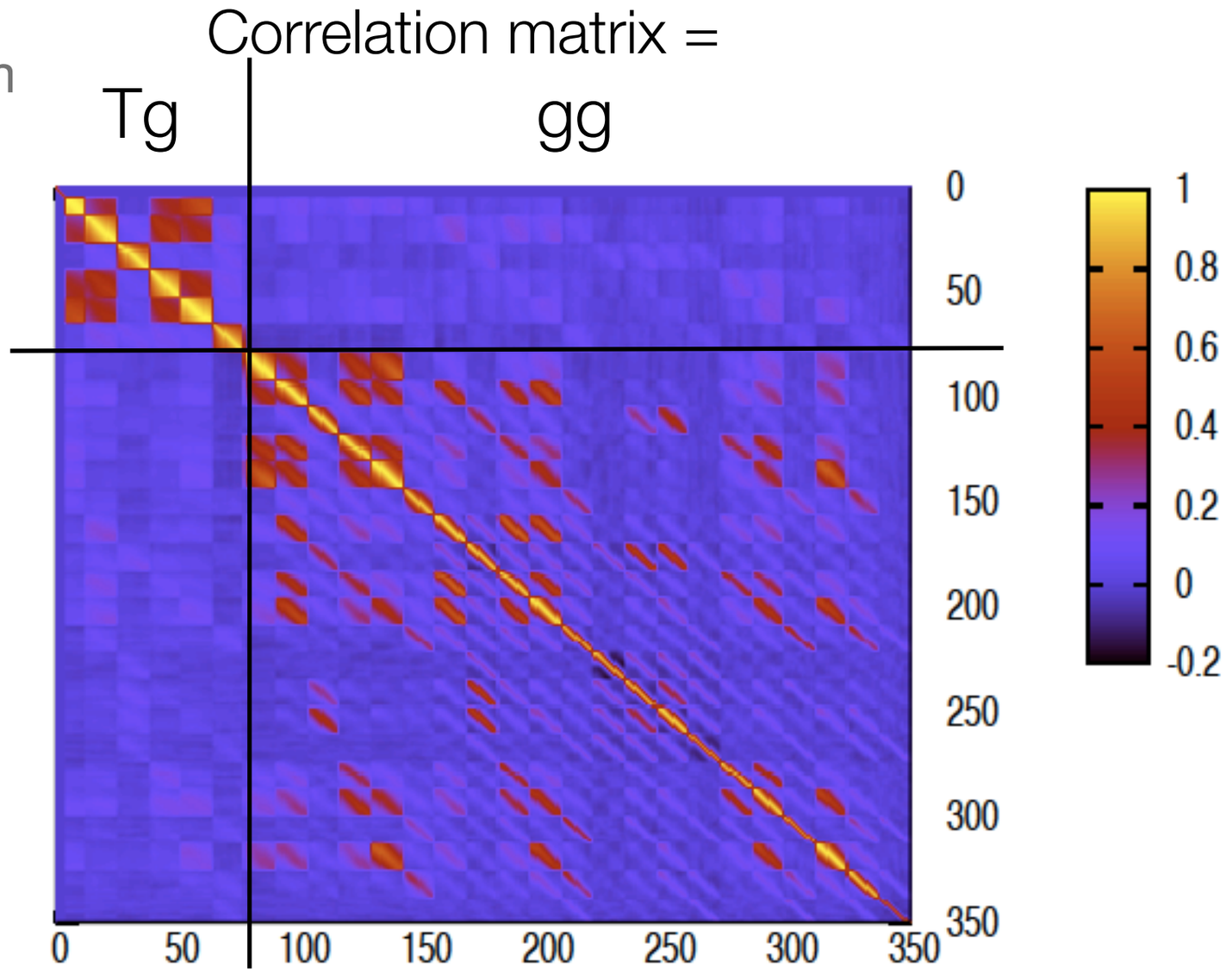
nuisance parameters



Monte Carlo likelihood analysis

Monte Carlo likelihood analysis

- Full Covariance Matrix (351x351) from 10,000 Monte Carlo mocks



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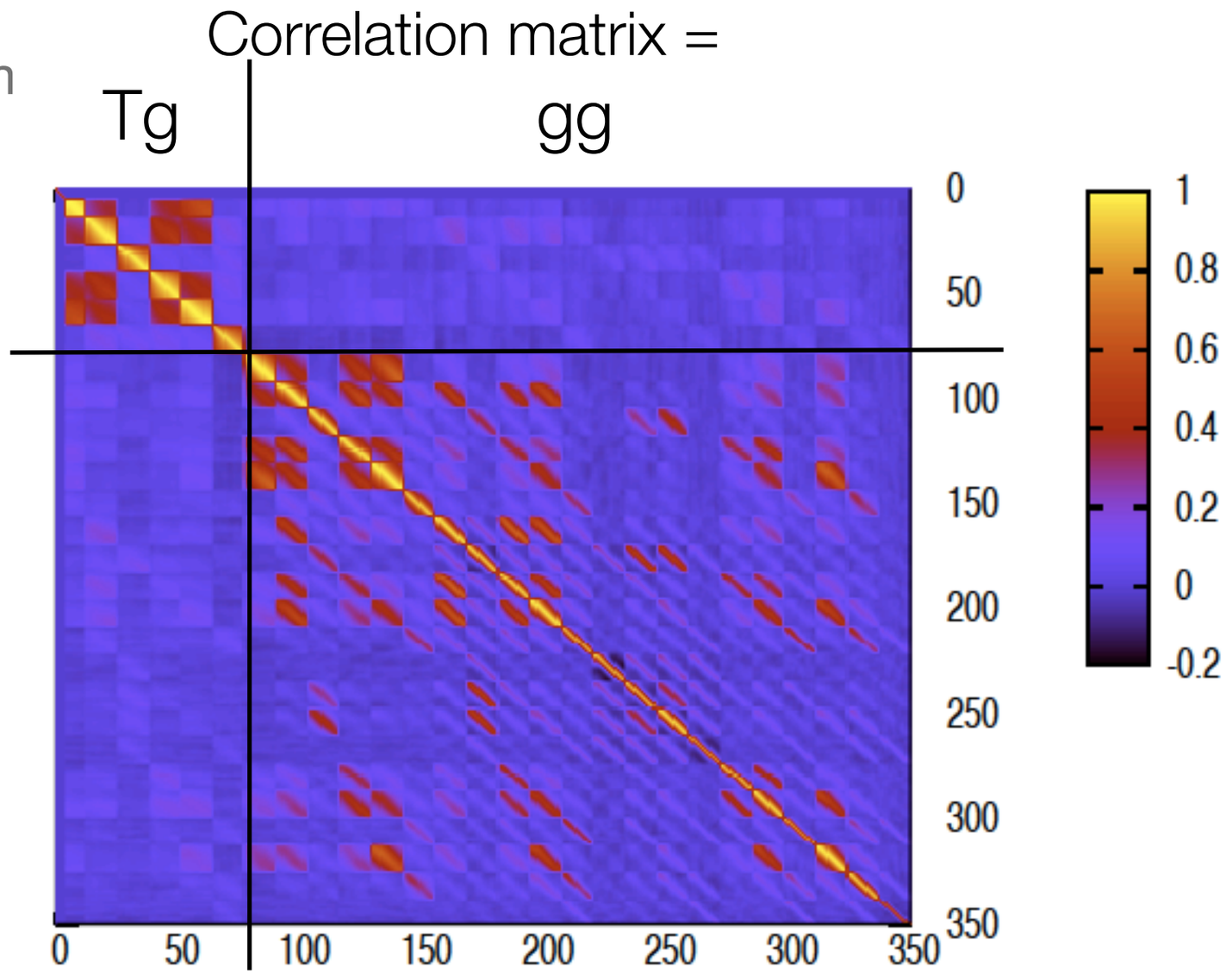
- Full Covariance Matrix (351x351) from 10,000 Monte Carlo mocks
- Theory models: with modified Camb code
- **Monte Carlo** likelihood analysis, marginalising over (nestled sampling)
  - cosmology (7 params)
  - 6 nuisance parameters b_{0i}
  - 3 nuisance parameters κ_i: **stellar contamination**



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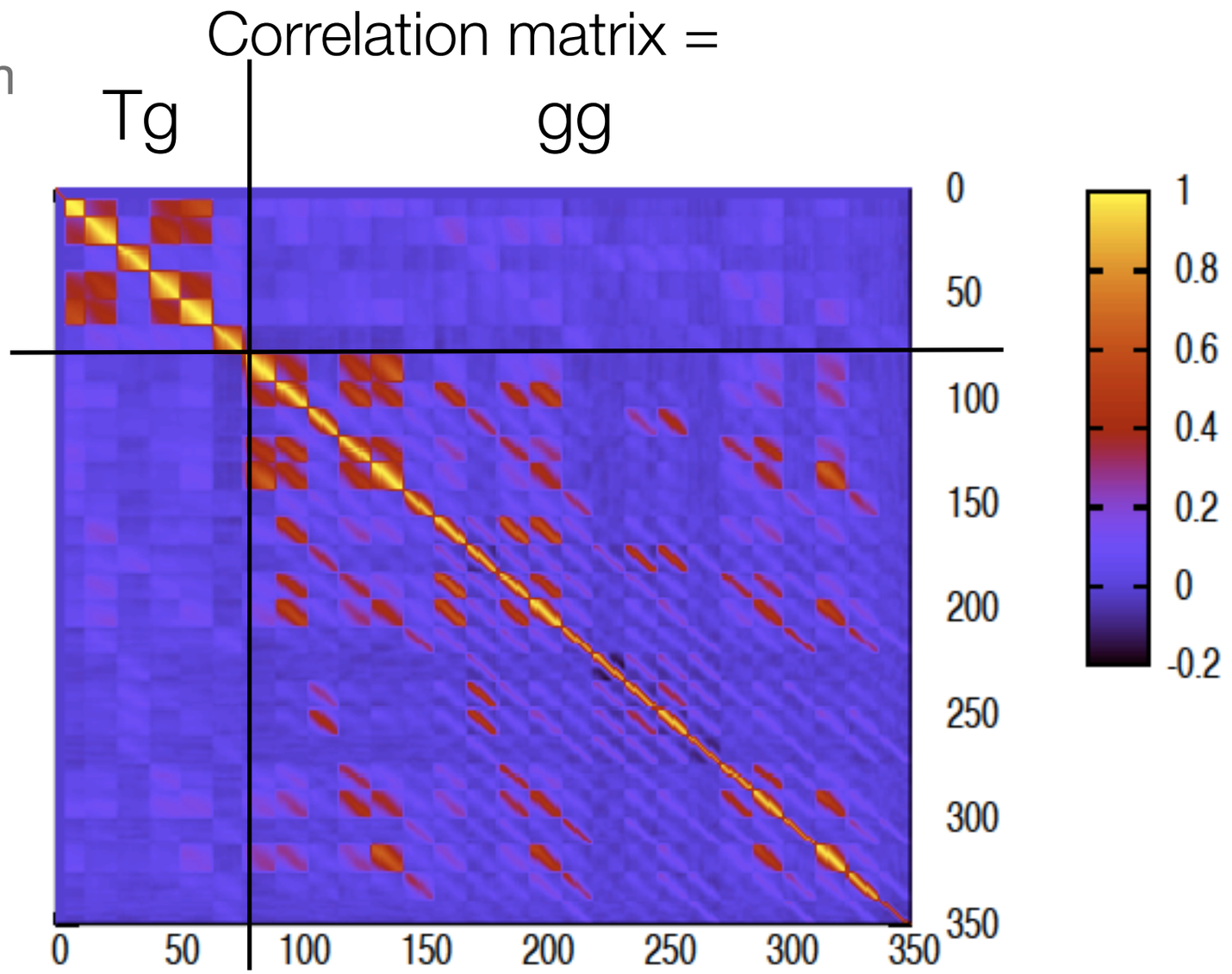

- **Results with all data + CMB TT prior:**

at face value, **$42 < f_{NL} < 68$!!!** @ 95% c.l.

Further study to understand this...

Systematics!

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- **Stellar contamination** fraction κ (SDSS samples)

Systematics!

- **Stellar contamination** fraction κ (SDSS samples)

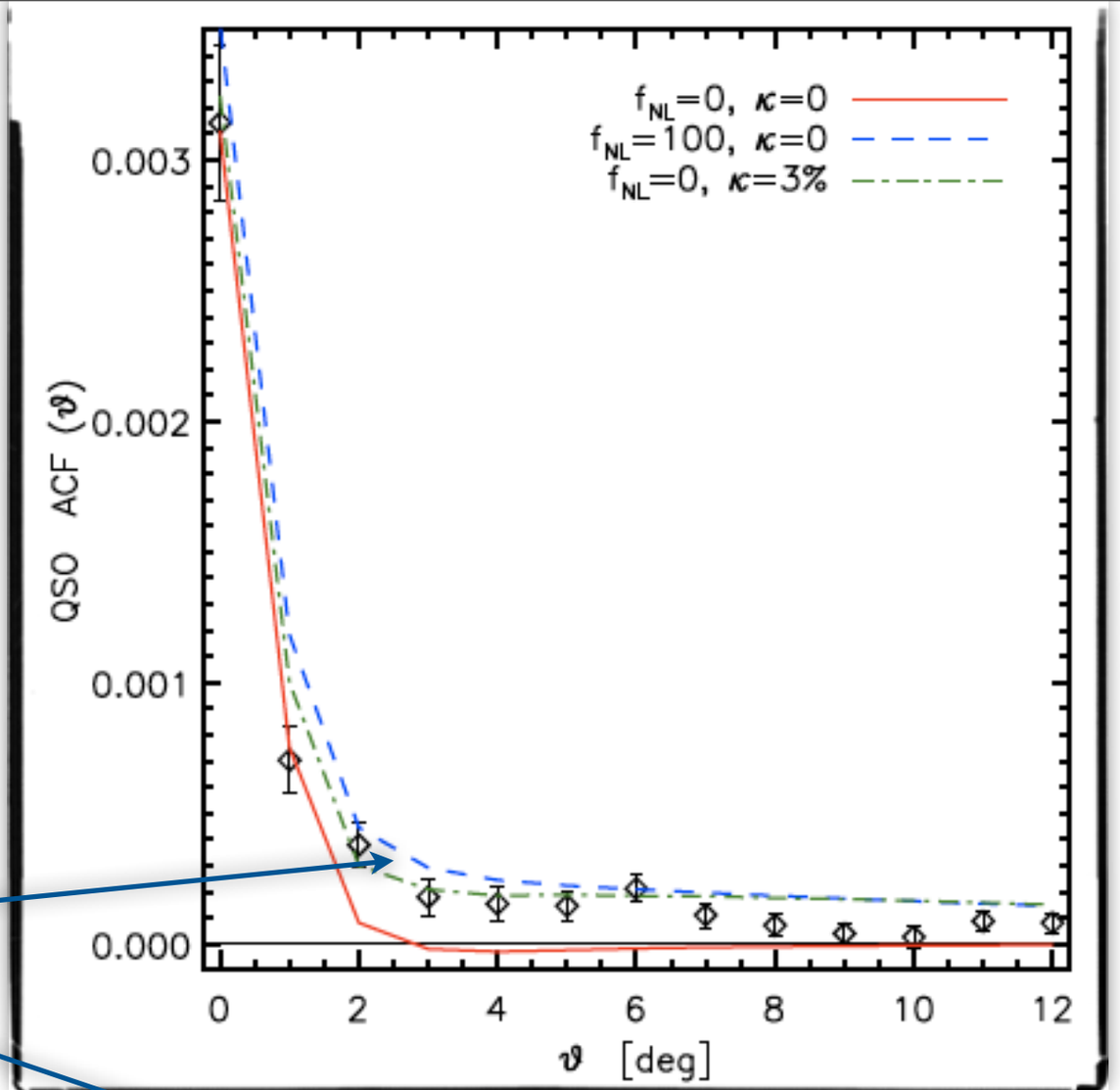
$$\tilde{\xi}^{gg}(\vartheta) = (1-\kappa)^2\,\xi^{gg}(\vartheta) + \kappa^2\,\xi^{\rm star}(\vartheta)$$

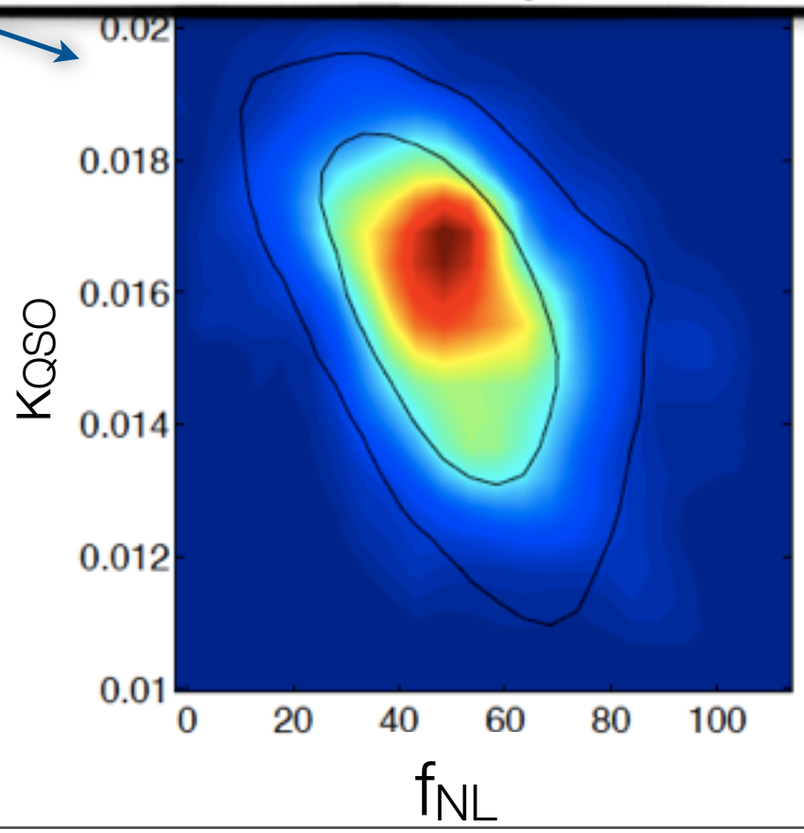
  - Degeneracy in plateau

f_{NL} = 100 ~ κ = 3 %

  - forcing κ = 0 %, best f_{NL} ~ 79
  - forcing κ = 2 %, best f_{NL} ~ 16

- Prior from ⟨qso-stars⟩ does not solve (only ~1%)
- Residual systematics?





QSO systematics

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[plots by A. Ross]

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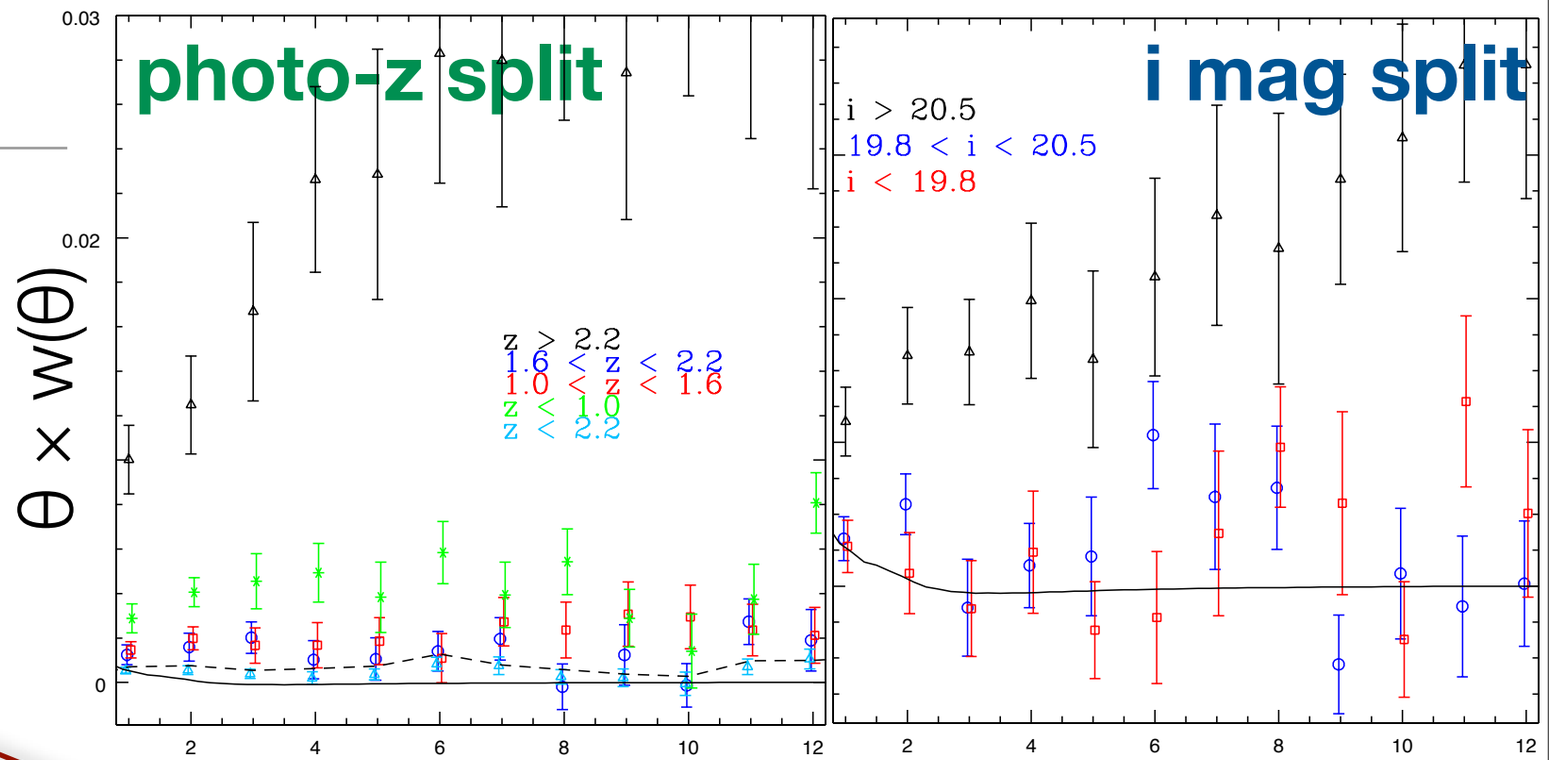
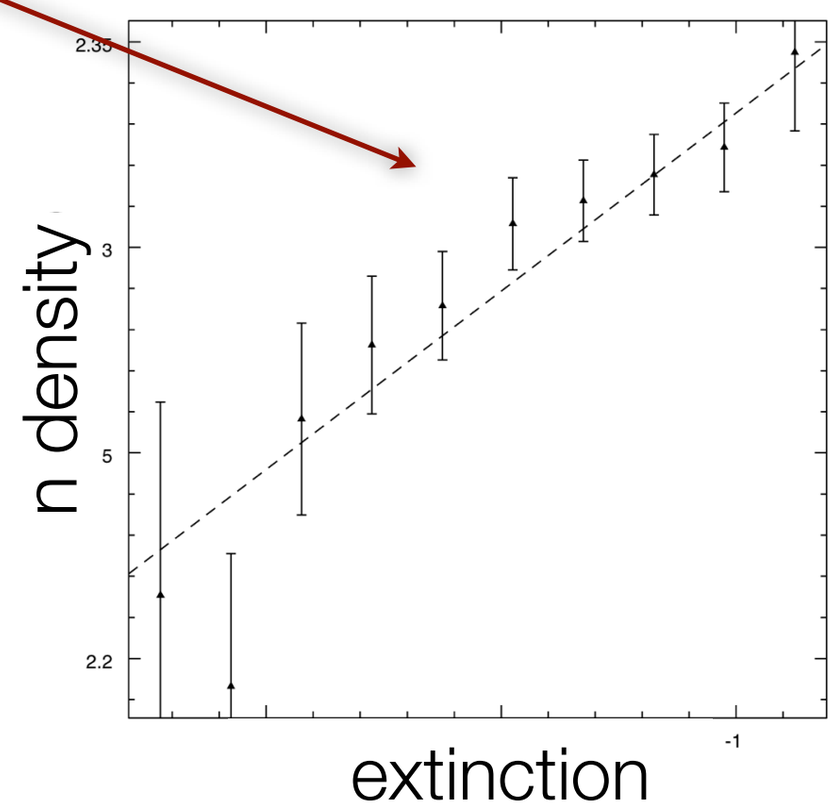
- Splitting by photo-z: **worse**
  - Higher excess power at high z
  - Cut? But then correlation density-extinction, and other systematics
- Splitting by i-mag also unstable
  - Large-angle ACF fluctuates





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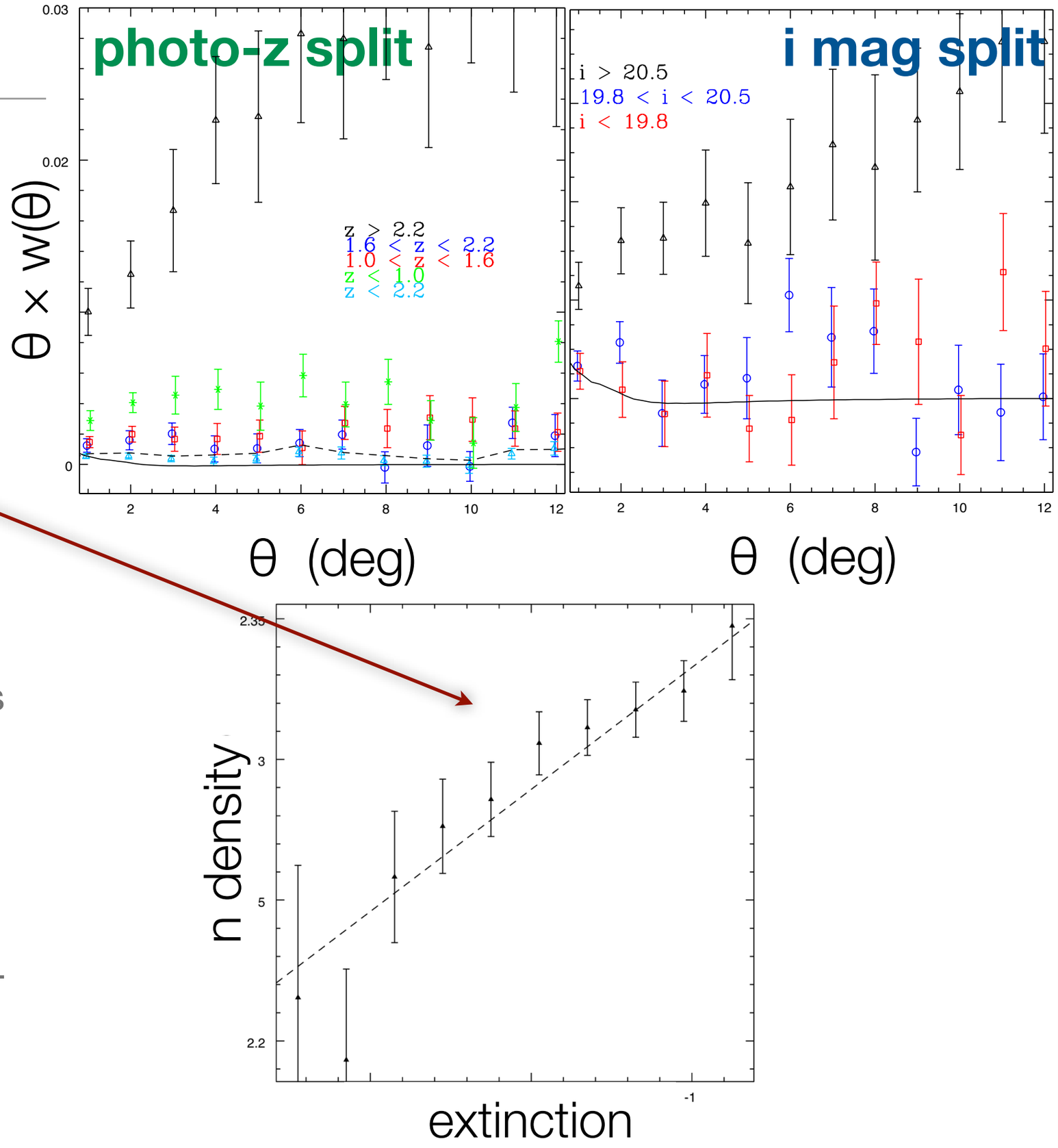
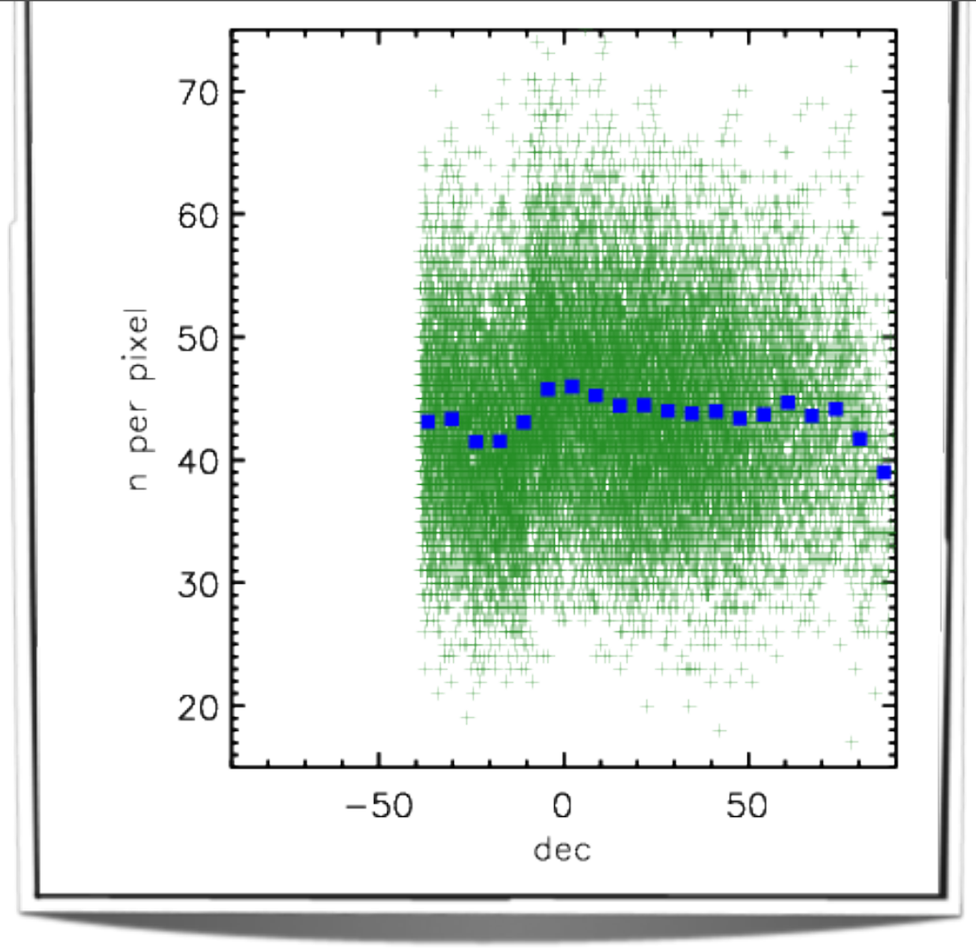
- Splitting by i-mag also unstable
  - Large-angle ACF fluctuates
- Implies some systematic relationships
  - should depend on color / magnitude
  - not clear - calibration issues?
- QSO ACF **unreliable** on large scales - too **faint**. BOSS cut is at mag i<19.9, these are at i ~ 21+ --> discarded.



NVSS systematics

NVSS systematics

- Known problem: number density changes in dec



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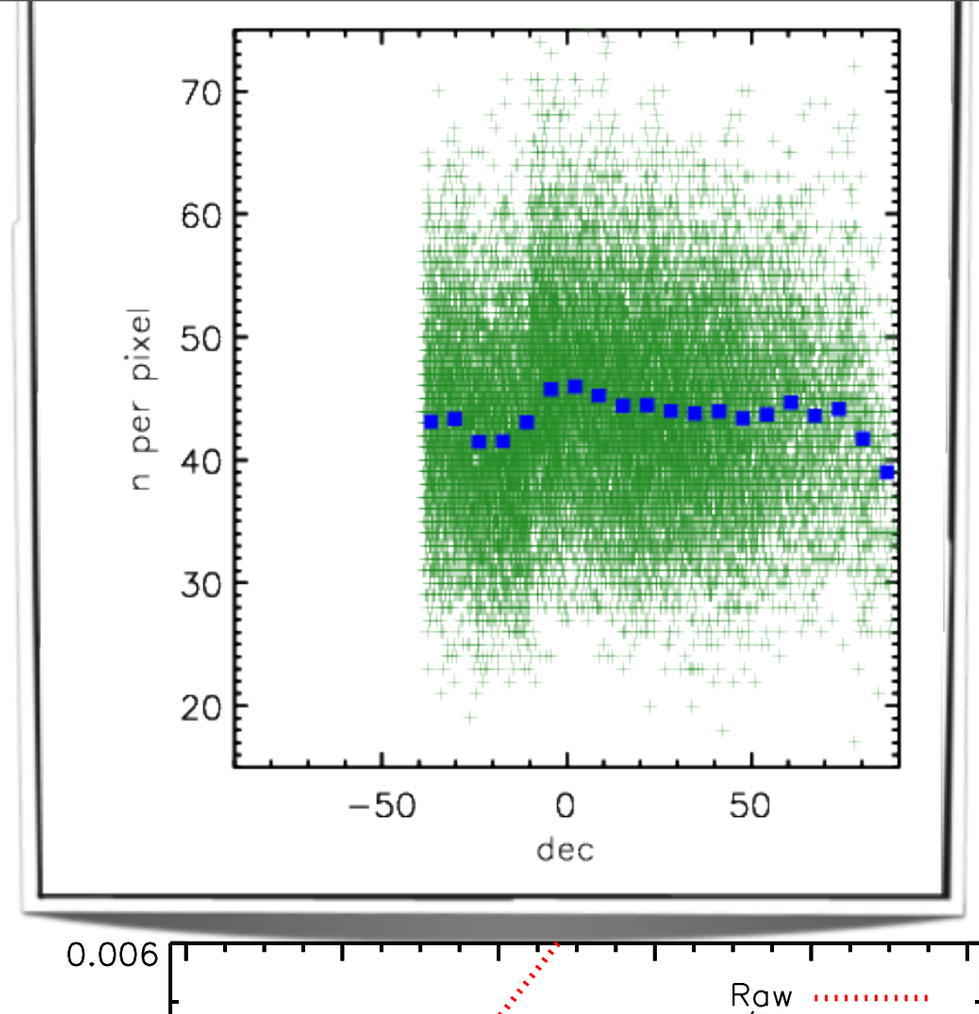

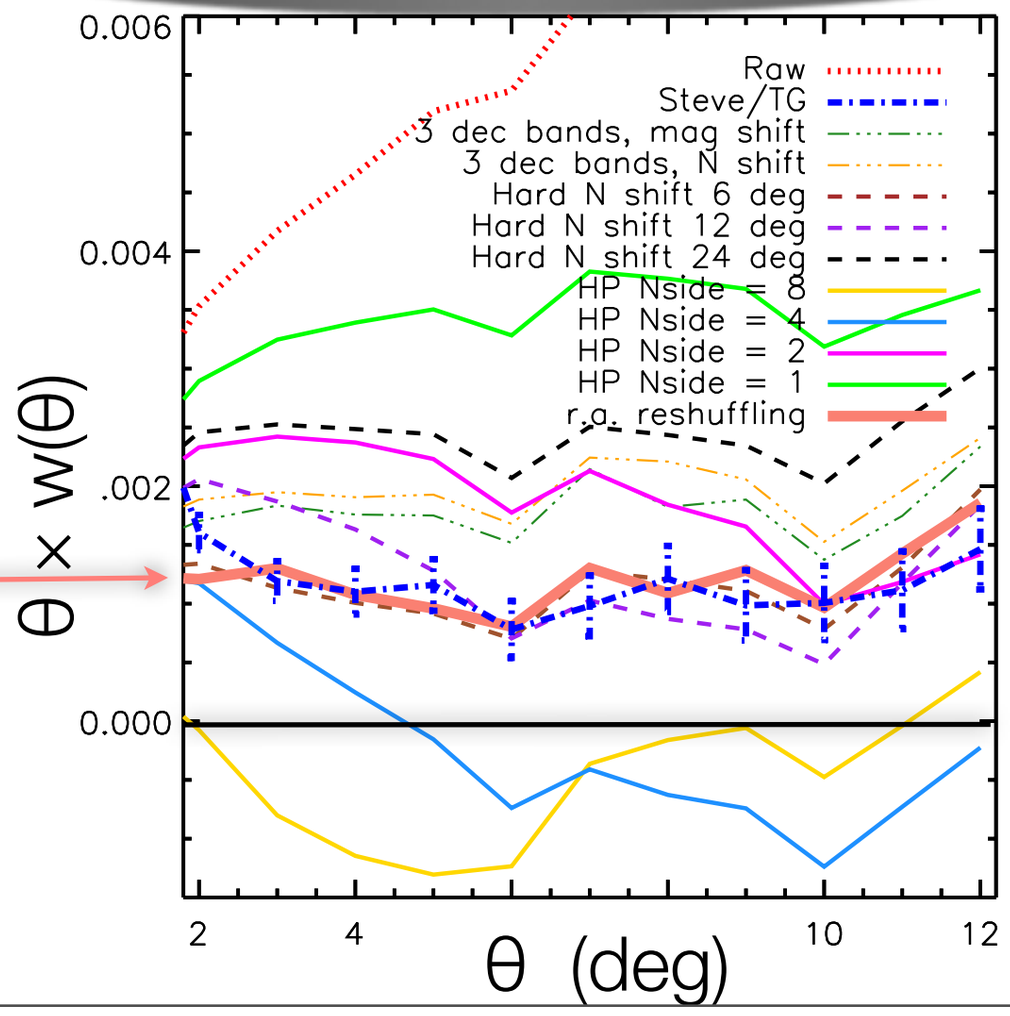

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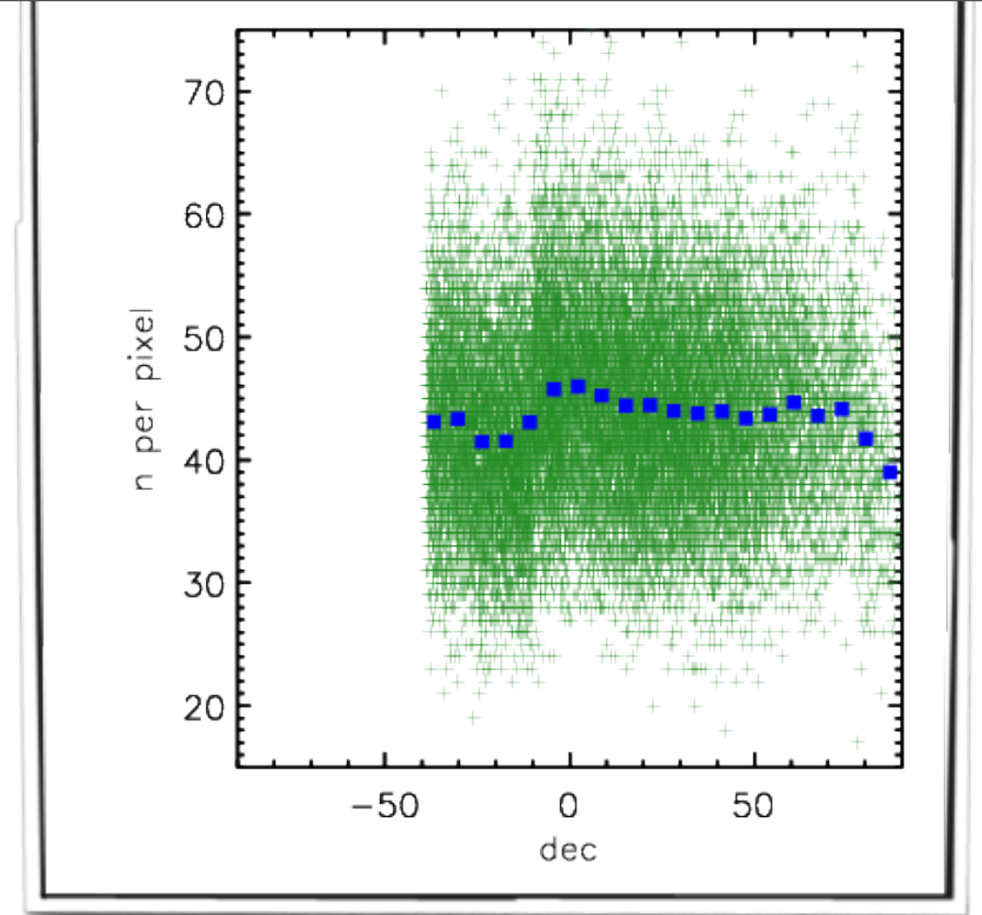
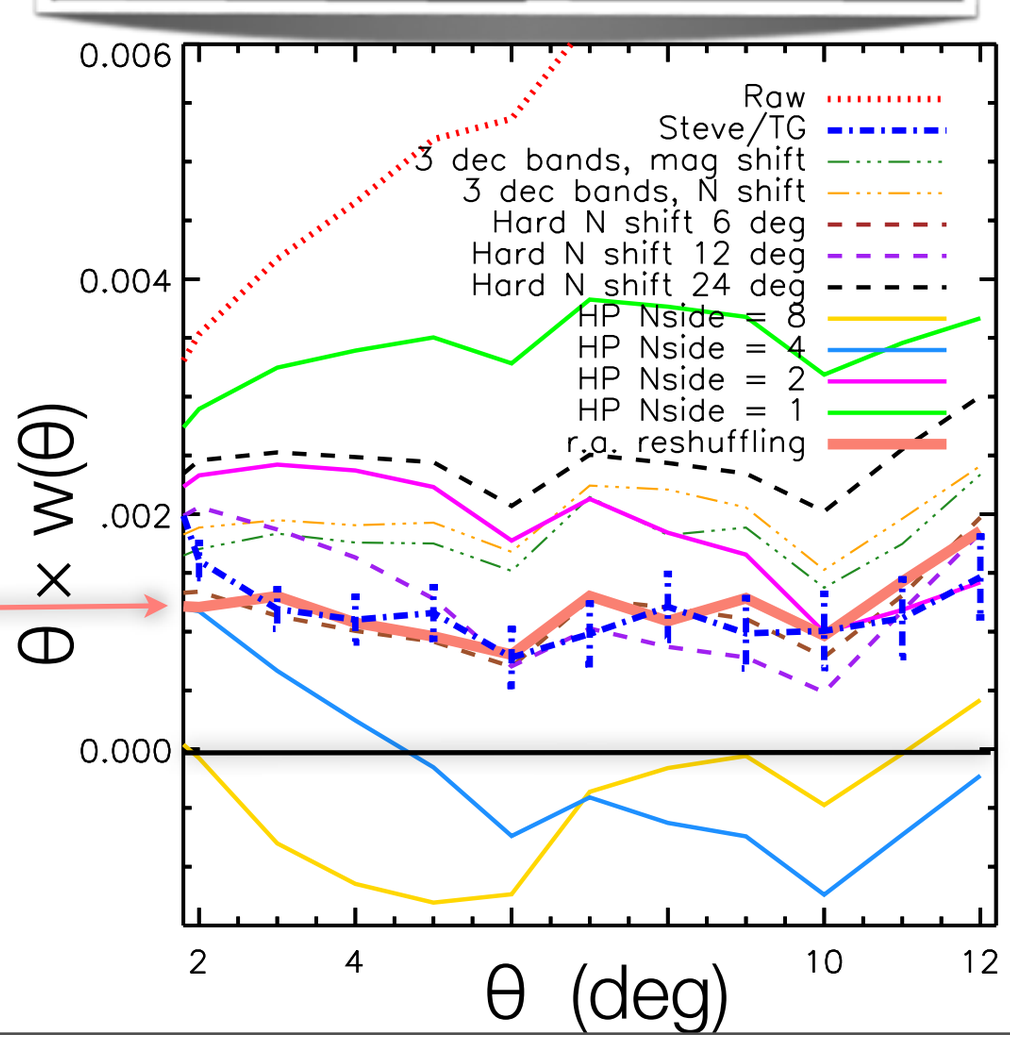
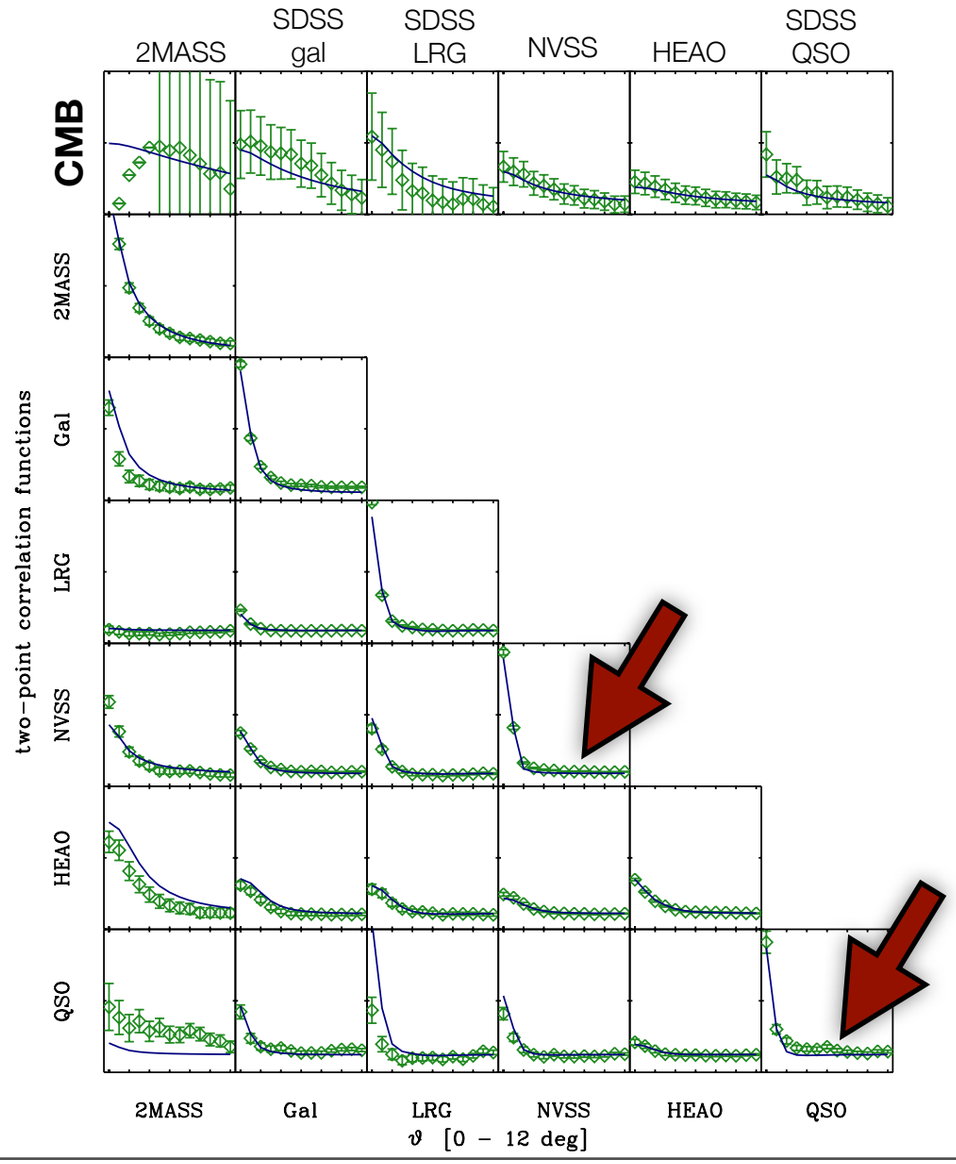
- Arbitrary, results vary; also smaller r.a. effect (lower n at ra > 240)
- **Discard this auto-correlation as well**





What can we trust?



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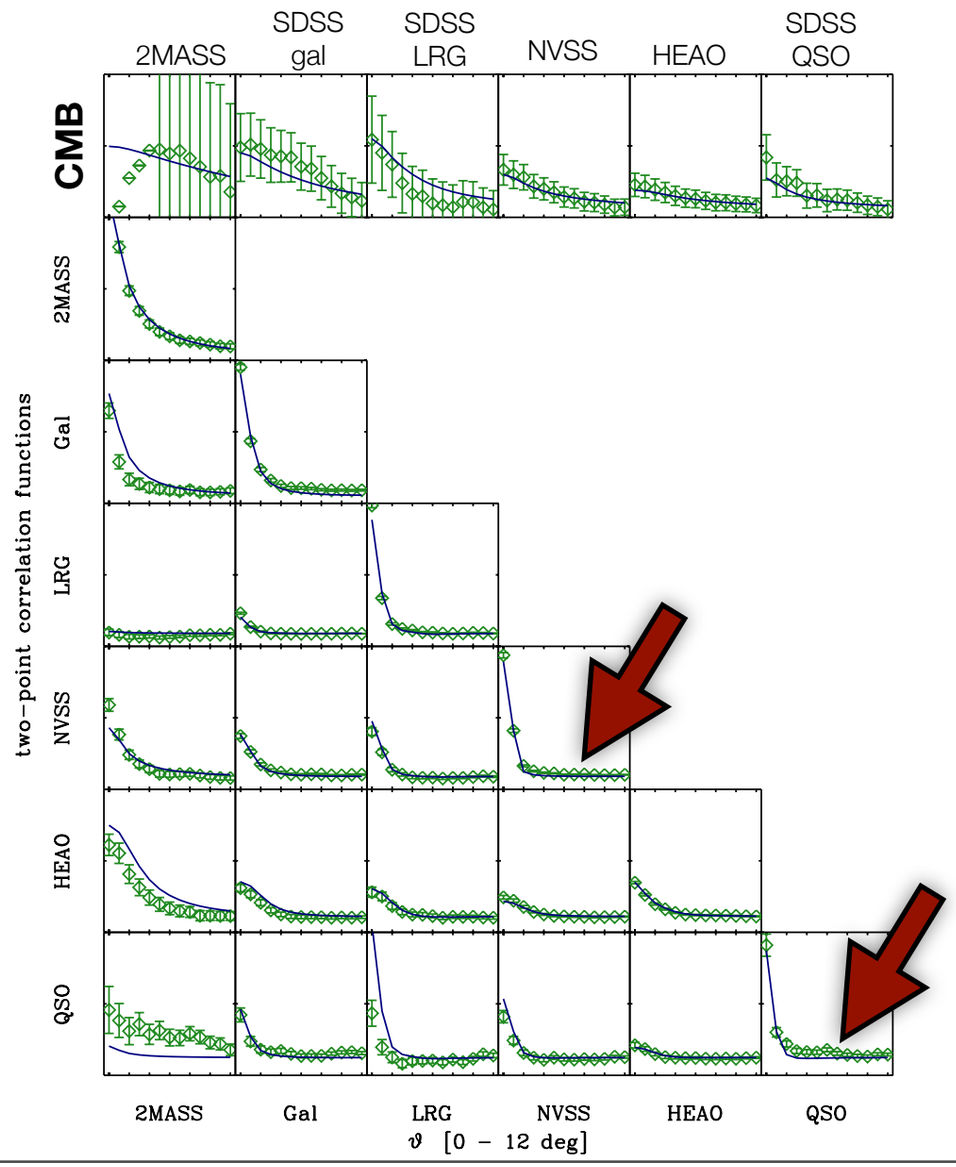

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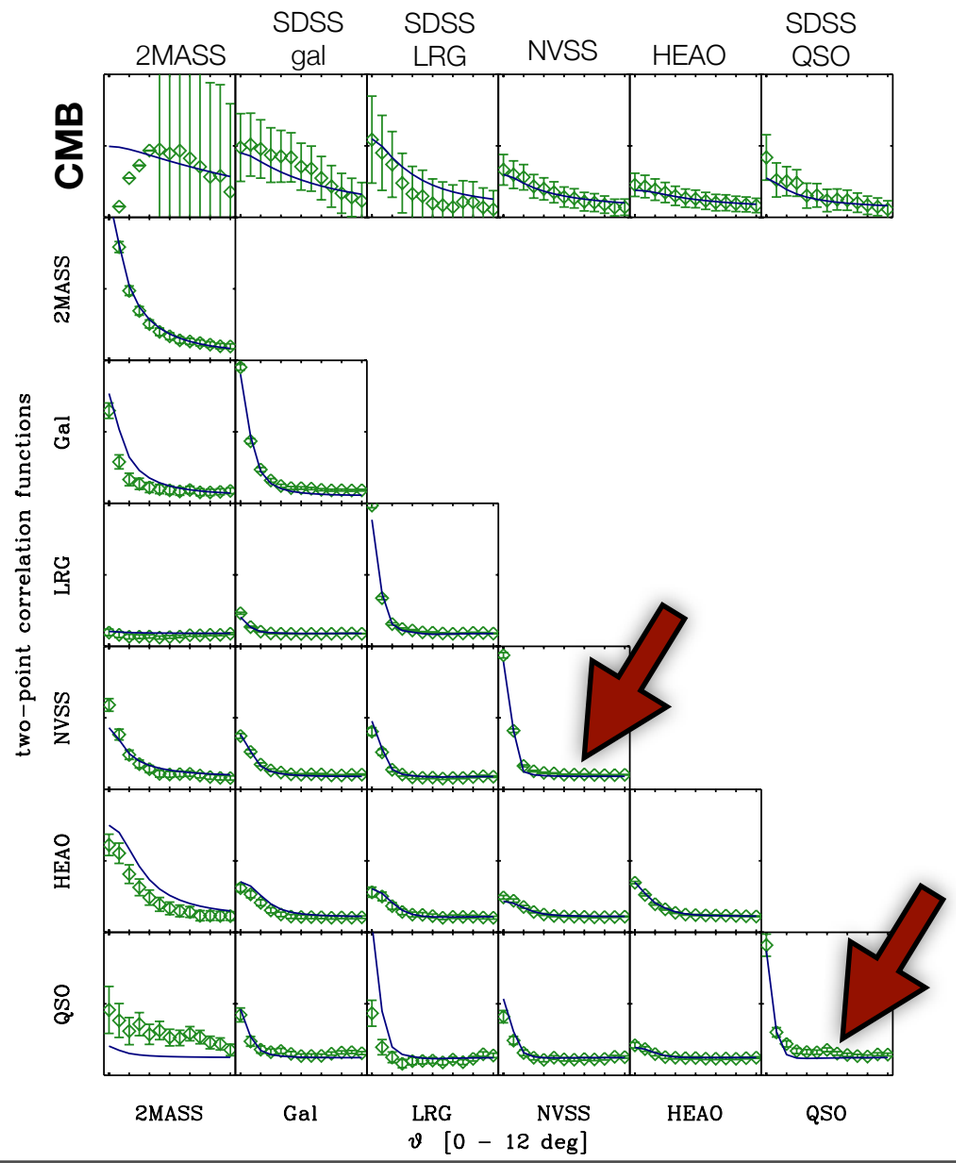

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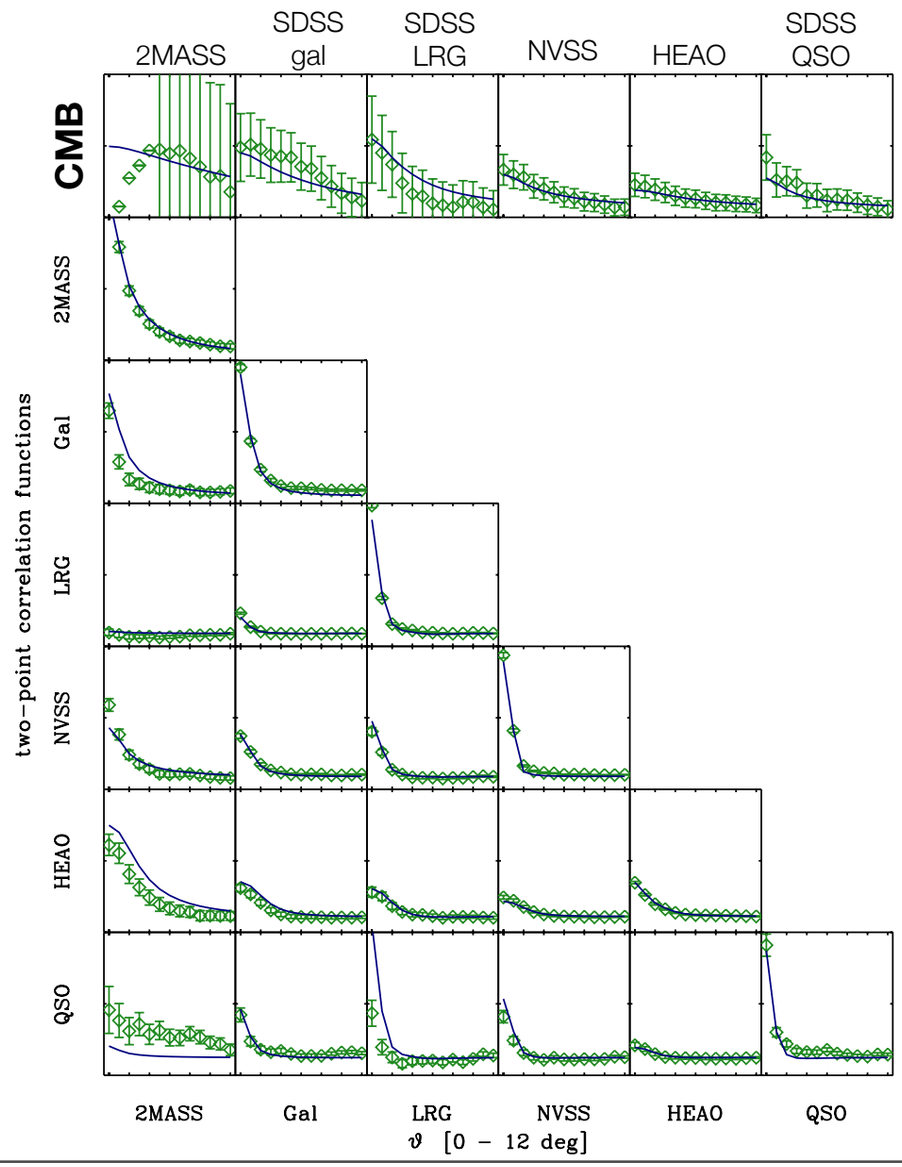

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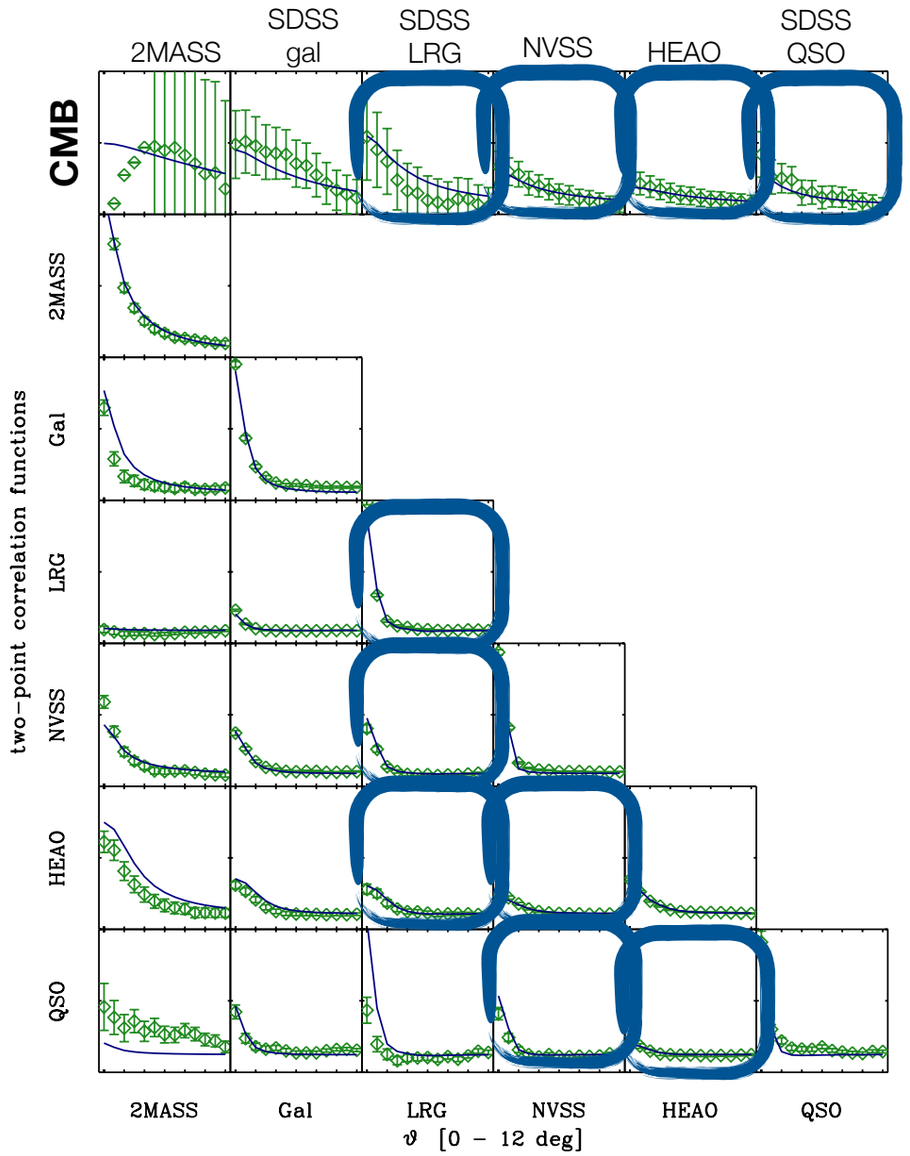

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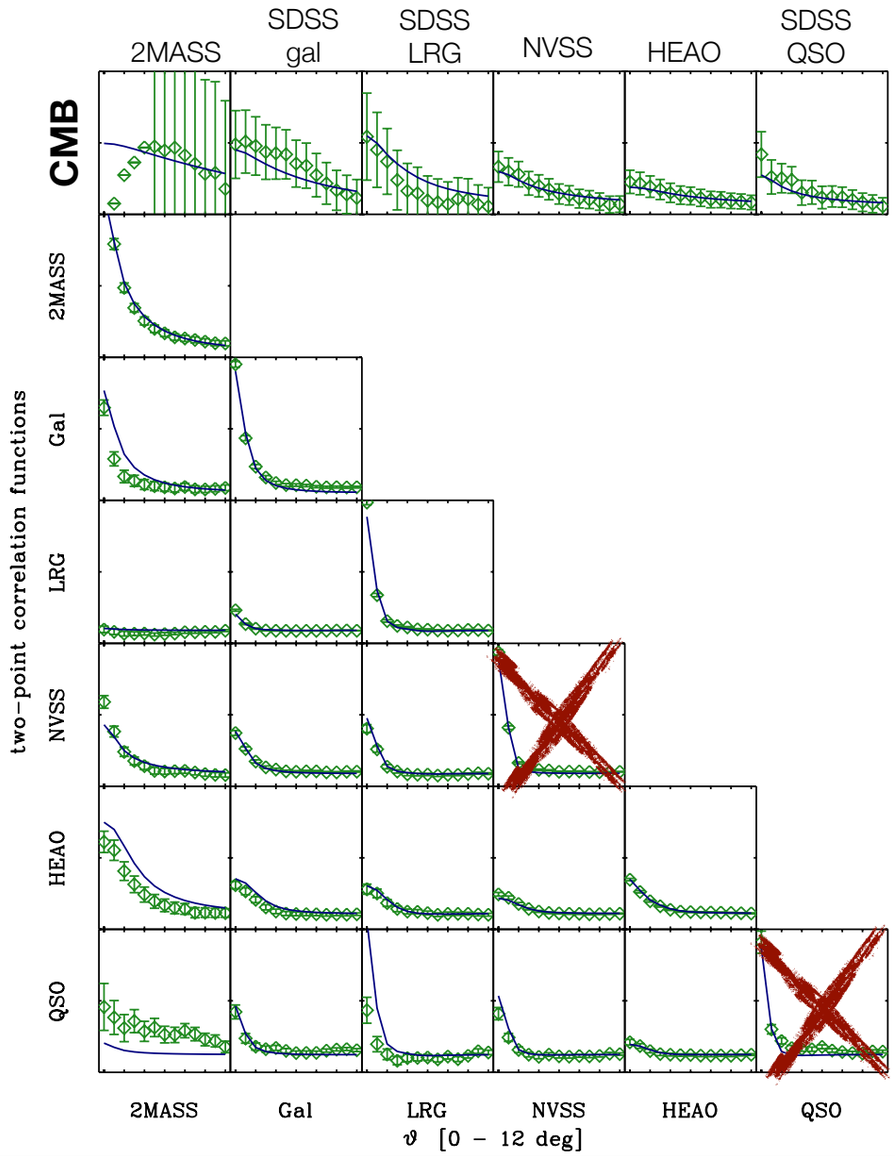

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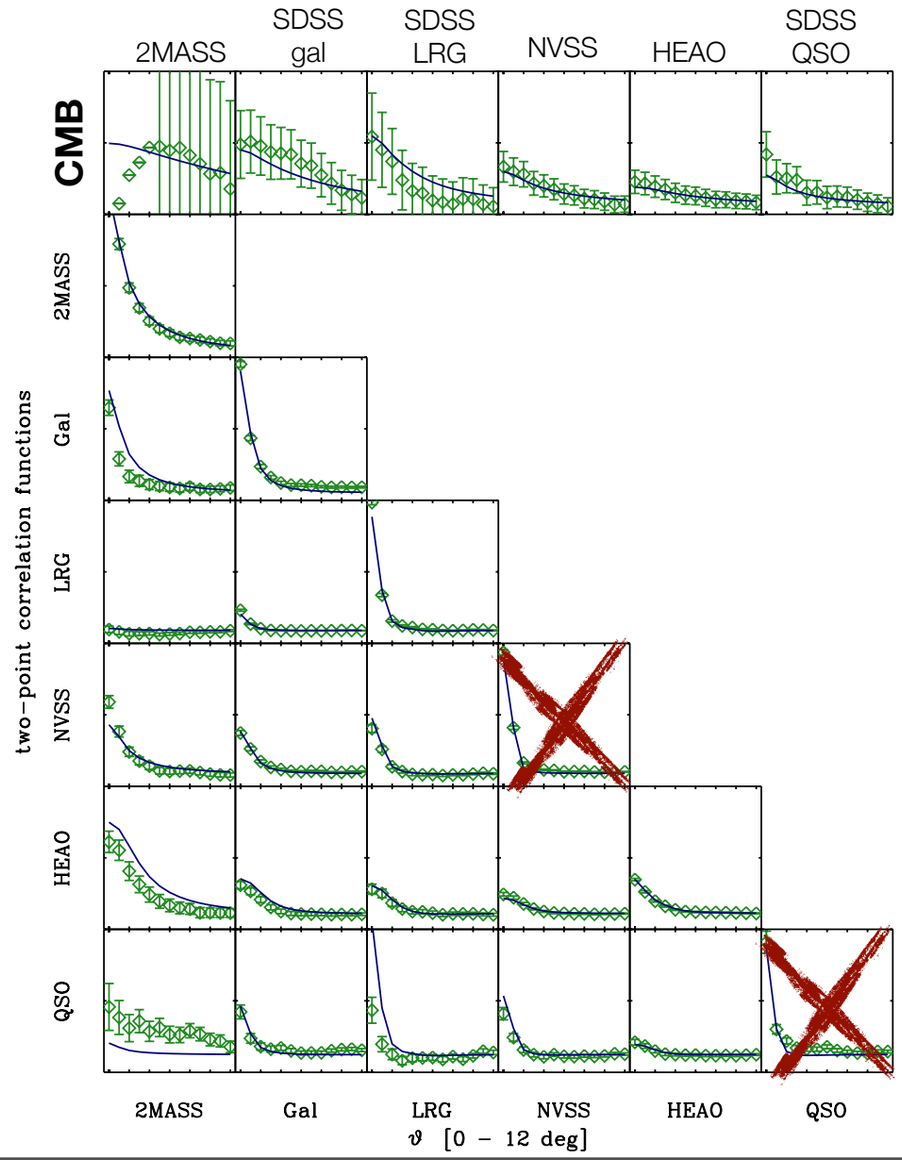
  - Fair: drop only NVSS, QSO auto-correlation
- **Cross-correlations safer** than auto-correlations, keep them
- if $f_{NL}(k) = f_{NL,\,pivot}\,(k / k_{pivot})^{n_{fNL}}$:
- All assuming $g_{NL} = 0$.

$n_{fNL} = 1.7 \pm 1.1$ @95%



Extension to galaxy clusters

[A. **Mana**, TG, et al. in prep]

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- Observables:
  - Counts N_i in richness bin i (N_{200}: # of red galaxies at $R < R_{200}$)
    - nuisance params: L_1, L_2, $\sigma_{N|M}$
  - Masses from weak lensing data
    - nuisance params: β
  - **Power spectrum**
    - nuisance params: σ_z, B, q_{NL}

$$N_i = \int dz \int dN_{200} \frac{dn}{dM} \frac{dM}{dN_{200}} w(N_{200})$$

mass function

Jacobian of scaling relationship

richness bin selection

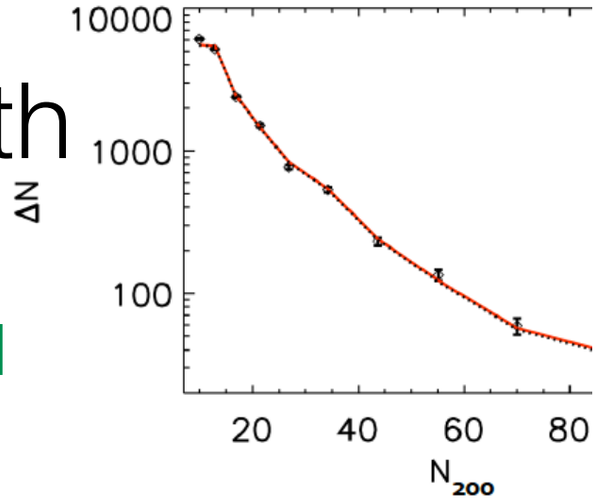
$$P(k) = b_{\rm eff}^2 (1 + q_{\rm NL} k^{3/2}) f(k) P_{\rm lin}(k)$$

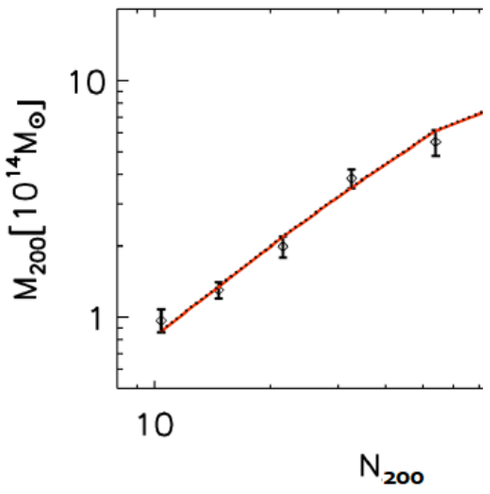
simple non-lin model

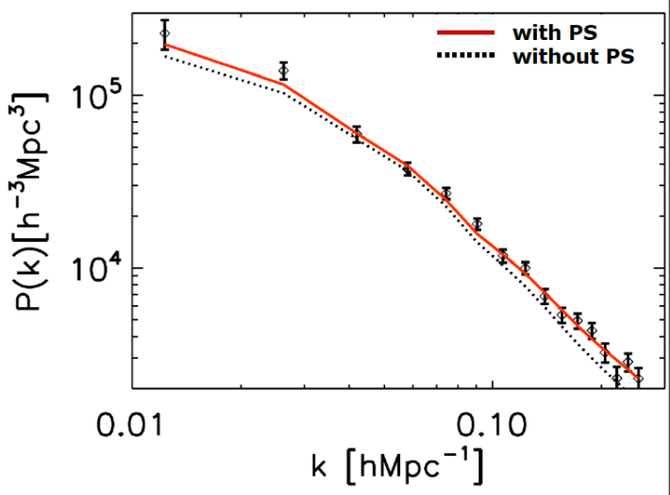
photo-z smoothing

Cosmology with MaxBCG

[A. **Mana**, TG, et al. in prep]







[plots by A. Mana]

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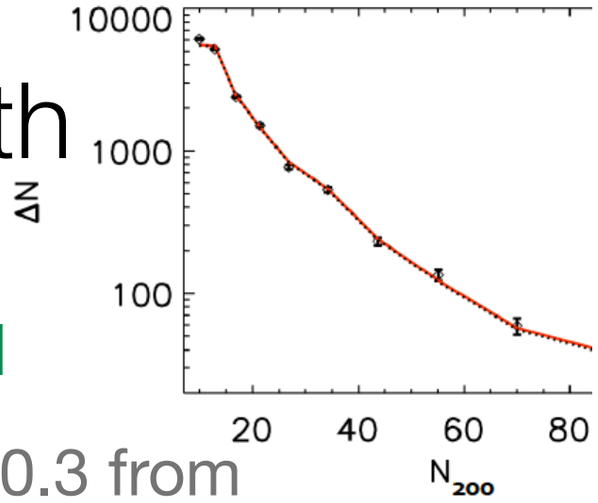

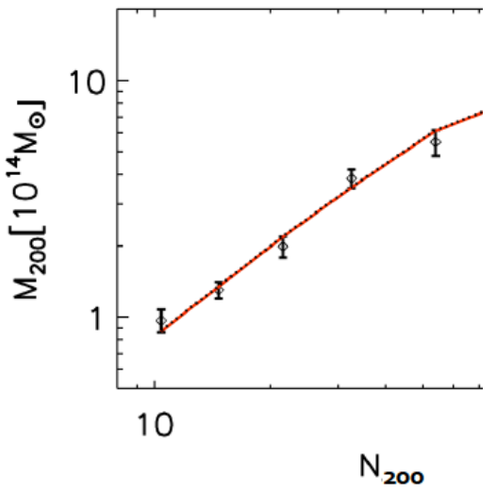

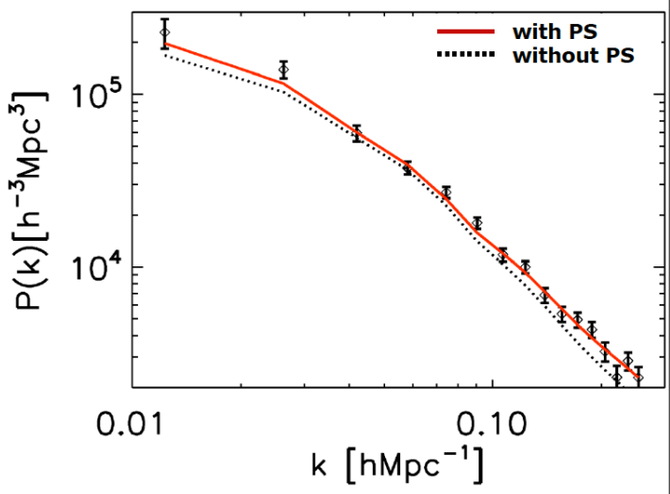

- 14,000 clusters to z < 0.3 from SDSS-DR7 [Koester et al. 07]

[plots by A. Mana]

- Data and covariances:
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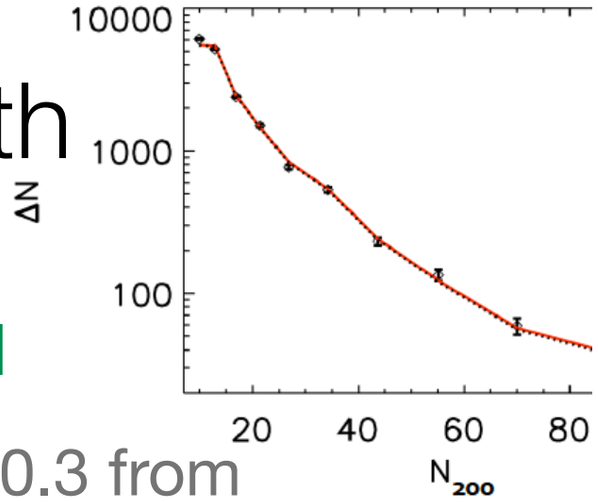

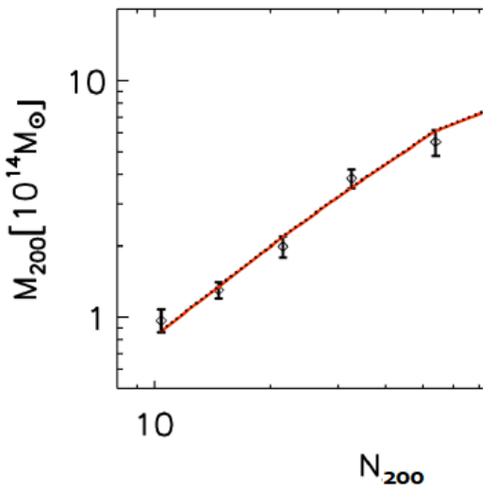

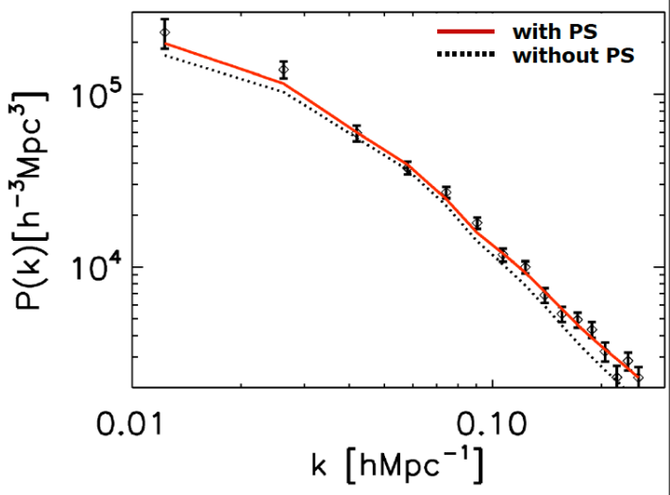

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- MCMC analysis over:
  - Cosmology (σ_8, Ω_m, **f_{NL}**)
  - Nuisance parameters (L_1, L_2, $\sigma_{N|M}$, β, σ_z, B, q_{NL})

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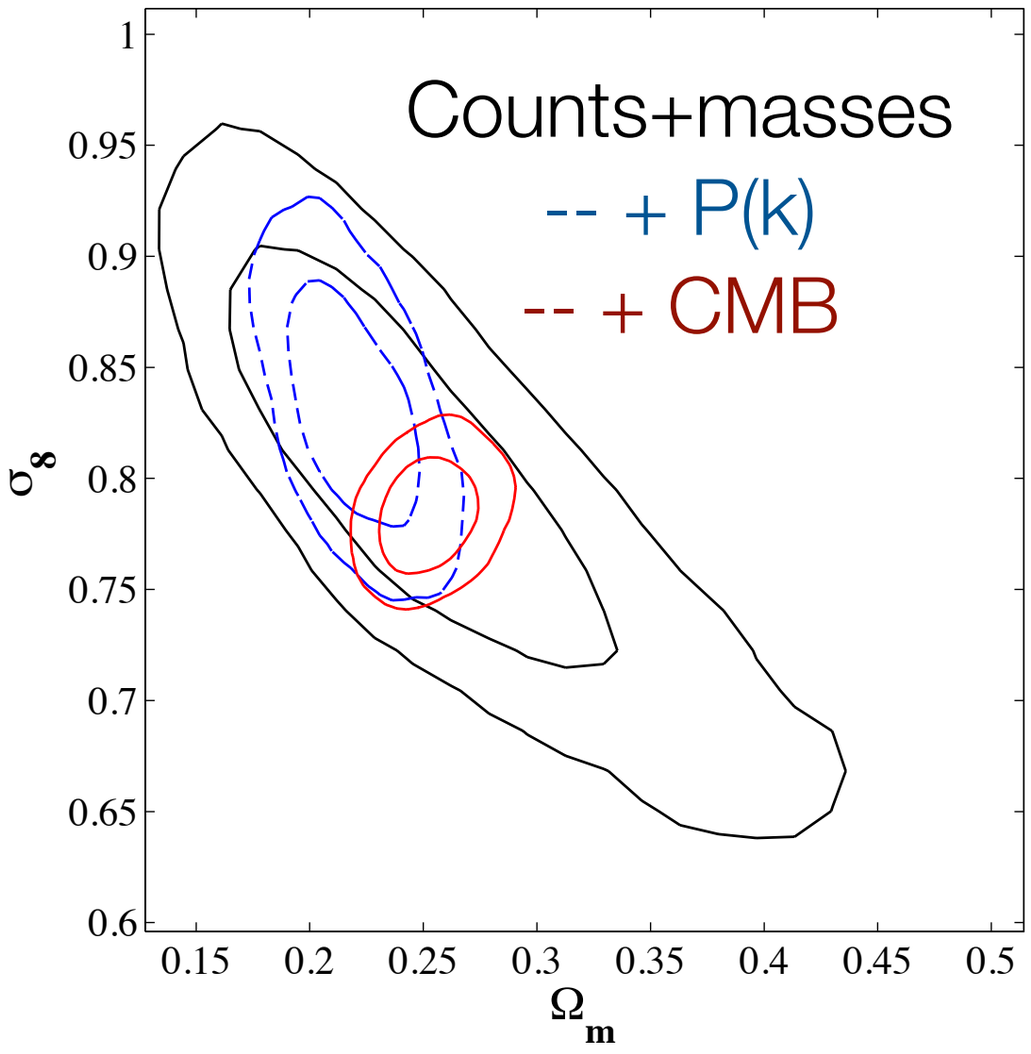


Counts+Masses: agree with Rozo et al. 09
adding PS: significant improvement!

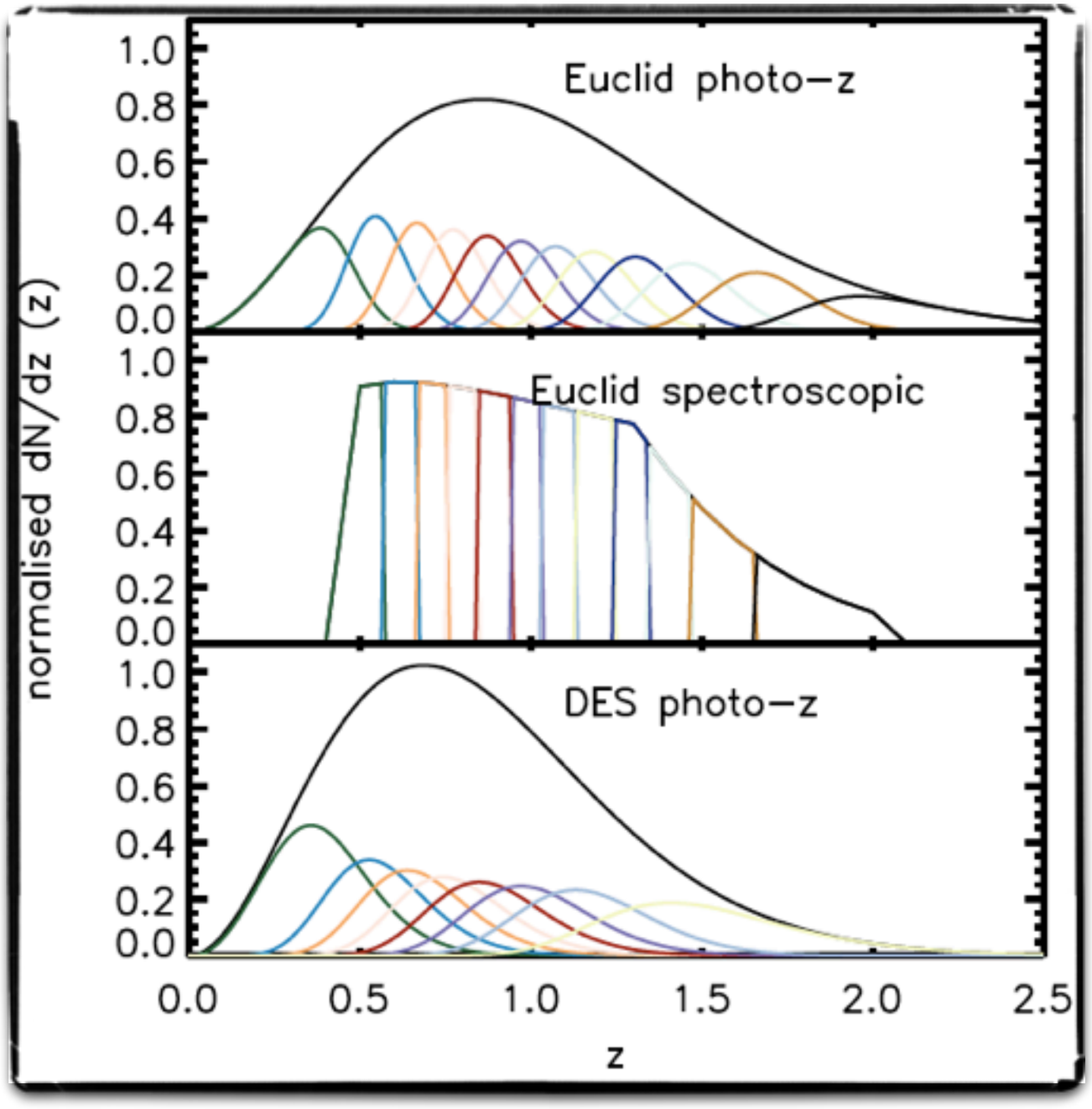
f_{NL} = 78 ± 150

Primordial NG with DES and Euclid

[TG et al. 11 MNRAS]

- Combining: lensing + galaxy clustering
- Following Hu & Jain 04
- Including primordial non-Gaussianity
  - **DES**: Fermilab-led mission

  - Starting now in Chile
  - Photo-z, deep to z~1.5
  - 300 M galaxies
  - 5,000 sq. deg
- **Euclid**: approved ESA mission
  - In L2 orbit, launch ~2019
  - **Imaging** (vis+IR): 2 bn galaxies
  - Slitless **spectra**: 80 M galaxies
  - 15,000-20,000 sq. deg



Results

[TG et al. 11]

- **Combined** lensing + 2D gal spectrum Fisher forecast:

$$C_l^{\epsilon_i \epsilon_j} \qquad C_l^{g_i g_j} \qquad D_{l\alpha}^{\epsilon_i \epsilon_j} = \frac{\partial C_l^{\epsilon_i \epsilon_j}}{\partial \vartheta_\alpha}$$

$$F^x_{\alpha\beta} = f_{\rm sky} \sum_{l=l_{\rm min}}^{l_{\rm max}} \frac{(2l+1)}{2} \, {\rm Tr} \left[\mathbf{D}^x_{l\alpha} \left(\tilde{\mathbf{C}}^x_l \right)^{-1} \mathbf{D}^x_{l\beta} \left(\tilde{\mathbf{C}}^x_l \right)^{-1} \right]$$

[Hu & Jain 04]

- includes ⟨lens-gal⟩ spectrum

- Red: with Planck TT priors
- Euclid accuracy on local f_{NL}: ±3
- **DES: accuracy on f_{NL} ~ ±8**
- Running: n_{fNL} ~ ±0.12 if f_{NL} = 30
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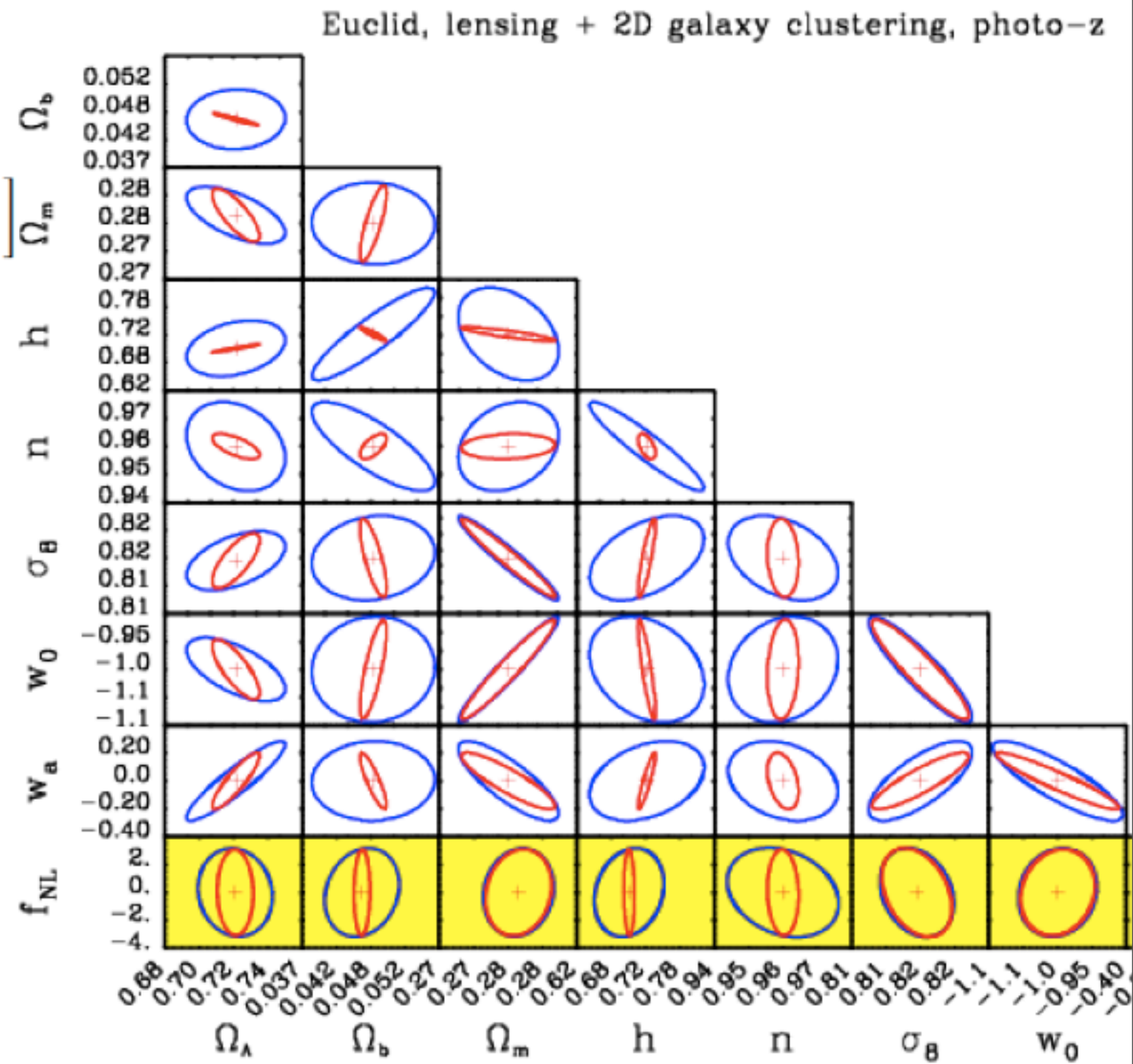

Results
[TG et al. 11]

Critical assumpion for f_{NL}: $b_{fiducial}(z) \sim (1+z)^{1/2}$, similar to Orsi et al. 09.

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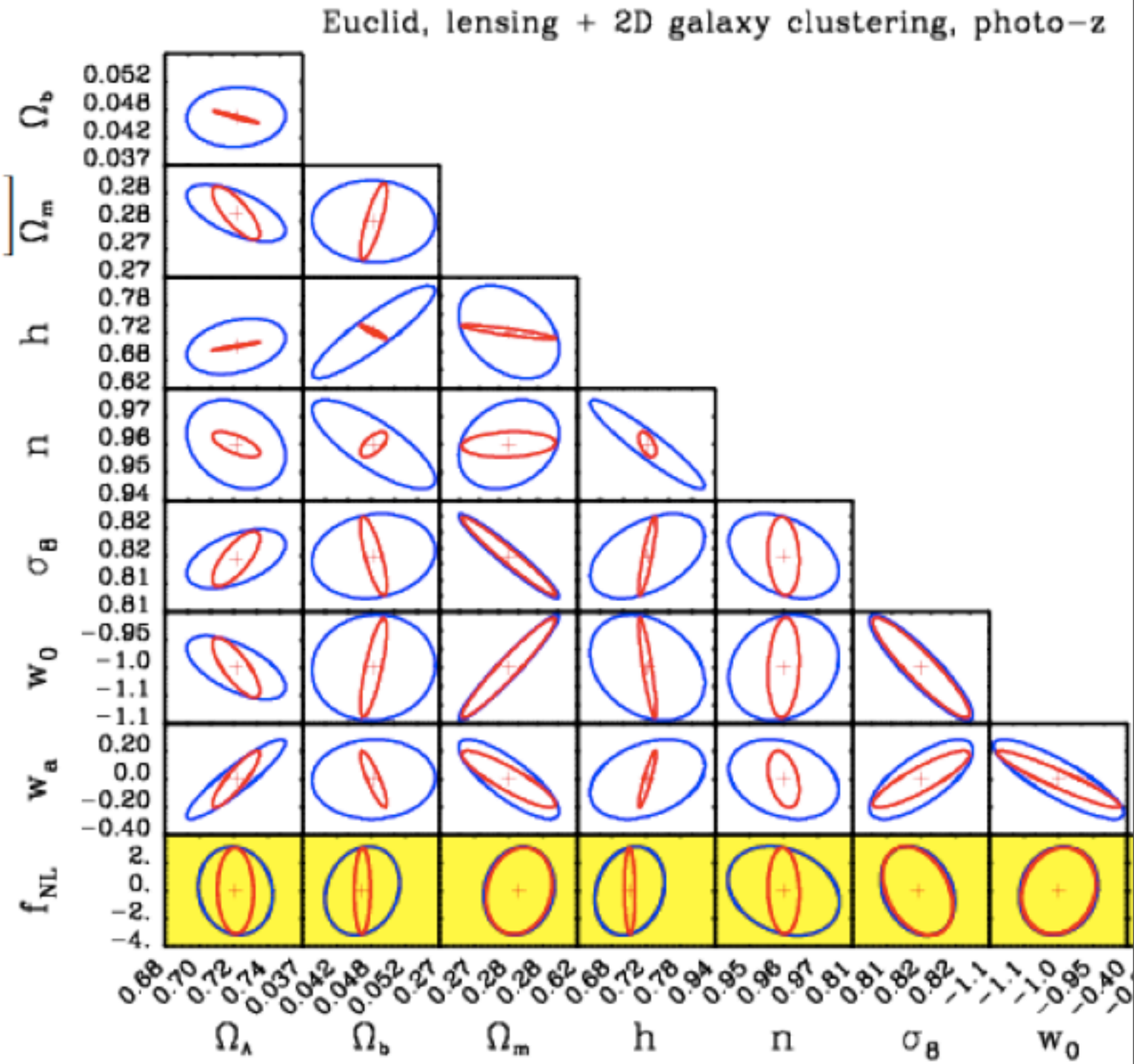

Conclusions & Future Work

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- **BOSS**: better systematics control
  - DR8 QSO?
  - LSS+ISW analysis with **3D clustering**
- **DES**: $f_{NL} \pm 8$
  gal-gal, CMB-gal, CMB-shear
- **Euclid**: $f_{NL} \pm 3$ ... if systematics under control

Subtraction of systematics